THE LRCM:
ASYMMETRIES, DETERRENCE AND SAL

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THESIS

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ASYMMETIES, DETERRENCE AND SAL

by

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This paper examines the many factors surrounding the potential deployment of the long-range strategic cruise missile focusing on: the technical and strategic asymmetries including guidance systems, air defense forces, nuclear weapons targeting vulnerabilities and strategic weapons essential equivalence; strategic implications including the missile's impact on the strategic balance and its potential stabilizing influence on a

deterrence model; and implications on Strategic Arms Negotiations.

It examines how the long-range cruise missile will add a measure of stability to the strategic deterrent balance and contribute to the restrained counterforce doctrine. The sea-launch cruise missile platform would provide a non-time sensitive reserve weapon capable of inflicting unacceptable damage on the adversary, hence increasing the stability of deterrence.

The LRCM:
Asymmetries, Deterrence and SAL

by

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This study is based on open-source literature. The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the Department of Defense.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

ABM	- Anti-ballistic missile
ADF	- Automatic direction finding
ALCM	- Air launched cruise missile
ASM	- Air-to-surface missile
ASW	- Anti-submarine warfare
CEP	- Circular error probability
CMP	- Counter military potential
EMP	- Electromagnetic pulse
EMT	- Equivalent megatonnage
FBS	- Forward base system
ICBM	- Intercontinental ballistic missile
KM	- Kilometer
KT	- Kiloton
L/D	- Lift over drag
LORAN	- Long-range navigation
LR	- Lethal radius
LRCM	- Long-range cruise missile
LSI	- Large scale integration
MAD	- Mutual assured destruction
MaRV	- Maneuverable reentry vehicle
MIRV	- Multiple independently targeted reentry vehicle
MPH	- Miles per hour
MRV	- Multiple reentry vehicle
NDV	- Nuclear delivery vehicle

NM	- Nautical mile
NRR	- Nonreprogramable reliability
OAR	- Overall reliability
OMNI	- Precision navigation aid
PSI	- Pounds per square inch
Rad	- Absorbed radiation dose
RBE	- Relative biological equivalent
R&D	- Research and development
REM	- Roentgen equivalent man
RES	- Reentry system
RR	- Reprogramable reliability
RV	- Reentry Vehicle
SAL	- Strategic arms limitation
SALT	- Strategic arms limitation talks
SFC	- Specific fuel consumption
SILO	- Storage container for underground ICMB
SLBM	- Sea-launched ballistic missile
SSKP	- Single shot kill probability
SSM	- Surface-to-surface missile
TERCOM	- Terrain contour matching
TKP	- Terminal kill probability
TRIAD	- Three U.S. strategic forces, bombers, ICBM's and SLBM's

I. STRATEGIC CRUISE MISSILE

A. INTRODUCTION

This thesis examines the many factors surrounding the potential deployment of the long-range cruise missile (LRCM) focusing on: technical and strategic asymmetries including guidance systems, air defense forces, targeting vulnerabilities and strategic weapons essential equivalence; strategic implications including the missile's impact on the strategic balance and its potential stabilizing influence on a deterrence model; and implications for strategic arms limitation.

Advances in technology play a key role in the development of weapon systems and methods of warfare. New weapons systems introduce new dimensions to warfare and raise thereby a multitude of political, military and economic implications. When a new weapons system has great potential against an adversary's strategic security system, it can greatly affect the world balance of power and inject new problems into the continuing negotiations concerning strategic arms limitation. Current technology promises capabilities which may have significant impact on the conduct of both tactical and strategic warfare. Recent advances in the micro-miniaturization of electronic components and sensor technology have resulted in the potential development of a new and unique class of weapon, the strategic cruise

missile, having the capability to deliver warheads on targets with great accuracy.

This study attempts to address the technical, political and strategic implications that the strategic cruise missile will have on the deterrent balance between the United States and the Soviet Union. An effort is made to provide the reader with sufficient background in a number of key areas to allow a full understanding of and appreciation for the great complexities involved in analyzing the "total" strategic picture.

1. <u>Background</u>

a. Cruise Missile

The cruise missile is not a new weapon system concept. Guided missile development can be traced to 1930 when a pulsejet engine was patented by a German engineer. This engine was perfected during WW-II, allowing the Germans to build the famous buzz bomb or V-1 missile. The V-1 was a pilotless pulsejet, midwing monoplane, lacking airlerons but using conventional airframe and tail construction. All guidance and control was accomplished internally by gyro stabilization and preset compass guidance. The missile carried a warhead weighing 1988 pounds.

Shortly after the end of WW-II the U.S. Navy began development of a cruise missile based on experiments with modified German V-1 Loon missiles. In 1947, the Navy began work on the REGULUS missile which achieved initial

operational capability in 1955. The REGULUS-I Missile was deployed as a Strategic Cruise Missile.

During the period 1954-1965 REGULUS Missiles were deployed on four diesel submarines, one nuclear submarine, three cruisers and one aircraft carrier. The REGULUS-I missile had a range of about 500 NM and a speed of 600 knots. It was controlled by a radar or radio command guidance system. The missile payload was a 3.8 MT nuclear warhead.

Ballistic missile technology improvements enabled the POLARIS missile to be developed decreasing the emphasis on cruise missile weapon systems. The REGULUS-I Missile procurement was cancelled in 1958 after some 500 missiles had been built. The REGULUS-II was cancelled at the same time along with an advanced twin ramjet, Mach 3.5 long-range penetration missile, the TRITON.

Strategic cruise missile research and development was not actively pursued in the U.S. from 1958 until recently when long-range cruise missile developments were initiated.

Like the U.S., the Soviets started developing cruise missiles shortly after WW-II. However, they continued to dedicate resources to research, development and deployment of new missile systems. The Soviets deployed their first missile, the SS-N-1, in 1958 just three years after the U.S. deployed the REGULUS-I Strategic Cruise Missile. In 1960 the Soviets deployed the short-range SS-N-2 STYX missile,

shortly after the U.S. Navy cancelled the REGULUS-II and TRITON. By 1961, the Soviets deployed their first submarine and surface-launched cruise missile, the SS-N-3 SHADDOCK. In subsequent years, the Soviets have continued their cruise missile developments deploying seven surface and subsurface missile systems and presently have one under development.[1] They have also developed six air-surface cruise missile systems. Their continued research and development programs would probably enable them to deploy state-of-the-art missile engine, guidance and airframe technology if resources were brought to bear.

U.S. cruise missile interest was revitalized by the 1967 Arab-Israeli War when the Israeli destroyer ELATH was sunk by a Soviet-built SS-N-2 STYX missile. U.S. interest initially was focused on tactical cruise missiles. The HARPOON tactical cruise missile program was born from this renewed interest. HARPOON was designed to be launched from surface, subsurface and airborne platforms. The LRCM program is an outgrowth of the HARPOON program technology and continues the capability of being launched from a standard 21" submarine torpedo tube.

On 6 June 1972, after the signing of the SALT I agreement, Secretary of Defense Melvin Laird emphasized the

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[1]See Appendix A.

importance of the submarine-launched cruise missile (SLCM) research and development program. As a result of that emphasis, a strategic type cruise missile is now in the prototype development stage. Production is projected to commence in late 1980 or early 1981.

The LRCM employs new guidance system technology enabling the missile to be launched from ranges in excess of 1000 NM, fly at altitudes of about 200 feet and strike a target with great accuracy. Micro-miniaturization of electronic components has enabled the development of computers having the capacity to store preprogrammed flight track data. The LRCM guidance system employs this new technology by interfacing an inertial navigation system and a terrain matching guidance system which continuously updates the missile's intended preprogrammed track position.

The LRCM's radar cross-section is very small and its low-altitude capability implies that it will be difficult to detect by known operational air defense radars. This factor promises high air defense penetration probabilities making the missile an effective non-time sensitive weapon, capable of destroying designated targets with surgical accuracy.

In the past, Soviet cruise missiles were considered tactical in nature. Recent analysis has indicated that that assumption may not be entirely accurate. Open-source literature on Soviet submarine launched cruise

missiles indicates that the Soviets would employ their SLCM's primarily as anti-ship weapons, with secondary missions of destroying land targets. VAdm V. S. Yakovlev, Deputy Chief of the Main Naval Staff, reported in his book, The Soviet Navy, the following:[2]

> "Today the main striking force of the navy consists of submarines and naval carrying aviation. They are capable of destroying enemy combat surface ships and submarines, as well as troop and cargo transports, in any regions of the world. In addition, they are capable of carrying out powerful nuclear missile strikes against enemy shore installations.
>
> "Nuclear submarines are the most powerful types of combat ships, capable of carrying out a variety of tasks...equipped with long-range missiles, homing torpedoes with nuclear charges, modern sonar equipment for detecting targets and other types of radio-electronic equipment. Thus, from great distances they are capable of destroying not only naval targets, but also installations located along the coast and in the enemy's rear areas....The communications equipment installed on the submarines enable them to maintain contact with their command and to receive orders at any point in the world.

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[2] Yakovlev, V.S. VAdm, The Soviet Navy, Moscow, DOSAAF Publishing House, Russia, 1969.

"Modern diesel submarines can successfully perform reconnaissance operations, harass enemy convoys, destroy enemy coastal installations with their missiles and carry out other combat tasks."

Recent congressional hearings have revealed that Soviet SLCM ranges have been underestimated and the weapon systems pose a formidable threat to the United States. Significant statements made at those hearings are as follows:[3]

1. The Soviet navy has had nuclear armed strategic cruise missiles for many years.
2. Soviet missiles are deployed now.
3. At the very least 50% of our population is held in jeopardy of those missiles.
4. Those Soviet cruise missiles are not regulated by any treaty.
5. We are unilaterally without arms in this area while the Soviets have purposefully developed and deployed strategic cruise missiles.

These revelations require renewed emphasis on the cruise missile as a strategic weapon system.

b. Asymmetries

U.S. and Soviet cruise missile posture displays enormous asymmetries as compared to the situation relative

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[3]U.S. Senate Hearings on the Strategic Cruise Missile before the Committee on Armed Services, 94th Cong., 1st Sess. on S 920, part 10, Research and Development, April 10, 11, 14, 17 and 21, 1975, p. 5153, Washington: U.S. Government Printing Office, 1975. (Henceforth known as U.S. Senate Hearings.)

to ballistic missiles. Geographic asymmetries between the United States and Soviet Union influence the sophistication and range a cruise missile must possess to attain similar targeting results. The U.S. coasts are readily accessible by medium-range missiles launched from submarines whereas the Soviet borders are inland, for the most part, requiring long-range missiles having more complex guidance systems. The Soviets moved a great portion of their industry from the European sector to east of the Urals during WW-II which further complicates the potential accessibility problem. These asymmetries limit the targeting choices available to strike counterforce and countervalue targets. The Soviets have a multitude of targeting options because the majority of the U.S. population and industry and many counterforce targets are within present potential cruise missile targeting range. Forty-three percent of U.S. cities over 100,000 inhabitants are within targeting range of the Soviets' present deployed cruise missile.[4]

The LRCM will pose a challence to present early warning systems and air defense forces in both the U.S. and U.S.S.R. Soviet air defense capabilities are enormous and far in excess of those of any other country.

Soviet cruise missile navigation guidance and engine technology does not need the degree of sophistication

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[4]See Appendix D.

that U.S. cruise missiles require due to the differences in geography and targeting. U.S. cruise missile navigation systems need a self-contained guidance capability to obtain the accuracies needed to strike targets at ranges in excess of 1000 NM.

Essential equivalence is based on the desire to match Soviet counterforce and countervalue capability and prevent the Soviet Union from attaining numerical superiority in strategic forces. The Soviets have the majority of their total megatonnage carried on ballistic missiles as compared to the U.S. which has the majority of their megatonnage carried on bombers. Increased warhead accuracies could potentially gain the Soviets a hard target kill capability and destabilize the deterrent balance which presently exists between the two countries. Nuclear warhead yields carried by Soviet long-range cruise missiles are small compared to "total" ballistic missile warhead yields, but utilizing these missiles as a threat against third-world countries and as a secondary weapon against U.S. or Allied targets would be formidable; this must be considered in the strategic arena.

c. Deterrence

The deterrence of general nuclear war is a fundamental national security objective of the United States. It is not a strategy of war, but one for peace, designed to convince the opponents that aggression is the least

attractive of all alternatives. Deterrence involves no physical restraint. It is a state of mind induced in antagonists as the outgrowth of threats, the known capability to carry them out, and the perceived will to execute, if necessary. The deterrent aim is almost universally accepted by U.S. decision makers and the people, but how to attain it is problematical. Deterrence depends on credibility and credibility depends on a potent force and the resoluteness to use that force if required.

A fundamental national security policy of the United States, promulgated by President Nixon, and still valid today, is to limit the "numbers, characteristics, and deployments of our forces [to those] which the Soviet Union cannot reasonably interpret as being intended to threaten a disarming attack."[5] That policy, translated into a Department of Defense planning criterion for nuclear sufficiency, prohibits "providing [any] incentive for the Soviet Union to strike the United States first in a crisis."[6]

The LRCM satisfies that policy and will afford the President of the United States that additional strategic flexibility essential for attaining U.S. foreign policy

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[5]Nixon, R. M., Foreign Policy for the 1970s, p. 131, 25 February 1971, Washington: U.S. Govt. Print. Off., 1971.

[6]Laird, M., Statement before the House Armed Services Committee on the FY 1972-76 Defense Program and the 1972 Defense Budget, p. 62, 9 March 1971.

objectives. The non-time sensitive nature of the missile cannot be perceived as a first-strike weapon, but its surgical strike accuracy will allow the president increased options in employing strategic weapons to demonstrate resolve should an adversary attempt to coerce the United States into an unfavorable political or military situation.

The missile's invulnerability contributes to the stability of the deterrence model making it a desirable reserve weapon system capable of inflicting unacceptable damage on the Soviet Union should they initiate a pre-emptive first strike against the U.S. The Soviets' deployment of cruise missiles is a demonstrated example of the confidence they place in the missile's potential contribution to deterrence and its capability to influence foreign policy objectives.

d. Strategic Arms Limitation

The Strategic Arms Limitation Talks (SALT) which opened in Helsinki on November 17, 1969, mark the beginning of a new era in Soviet-American strategic relations. For a decade or more, the two nuclear powers have geared their strategic policies to the dynamics of an expanding missile technology. Each has attempted to employ new technologies to weapon systems, possibly not so much because the results could be translated into practical political uses, but because it was felt that a failure to keep pace might forfeit some future advantage to the adversary. Almost

without intending it, the two powers have derived a security from this effort--a security based on a tacit understanding that neither could destroy the other without suffering destruction in return. The Vladivostok agreement signed on November 24, 1974, did not restrict the continued technical improvements in ballistic missiles and did not restrict the deployment of the sea-launched cruise missile being developed as a reserve weapon system. The Vladivostok agreement has not been published and hence the majority of the understandings are still unknown. The Vladivostok understanding in its present form is believed to provide that air-launched missiles with a range in excess of 600 Km (324 NM) will be counted against the overall ceiling of 2,400 delivery vehicles. The Department of Defense does not agree with that understanding and will address the issue at the SALT II negotiations. According to open-source literature, the Soviets are attempting to limit the sea-launched cruise missile to the same range restrictions which is not attractive to the U.S. because of the geographic and targeting asymmetries between the two countries.

II. METHODOLOGY

An examination of the long-range cruise missile is made using descriptive, correlational and explanatory methodologies. The descriptive methodology is used to formulate the problem and provide the background needed to understand the complex interactions between the technical, geographic and political asymmetries, how they influence the potential strategic balance, and how they may impact on a strategic deterrent model. A correlation methodology is used to analyze these asymmetries with the intent of highlighting those factors which could potentially favor one nation and destabilize the present and future strategic balance. Strategic and technical data are utilized to correlate present and projected potential targeting vulnerabilities. Weapon system performance characteristics are modeled to assess aggregate essential equivalence, its potential impact on the conduct of foreign policy and its impact on potential war fighting capabilities. An explanatory methodology is used to demonstrate the cause-and-effect relationships that arise when strategic force capabilities are significantly altered and what their resultant impact may be on a simplified strategic deterrence model.

III. ASYMMETRIES

A. TECHNICAL ASYMMETRIES

1. General

Current technology promises weapons with capabilities which could have a significant impact on the conduct of tactical and strategic warfare. The destruction of a target, either tactical or strategic, by means of either conventional or nuclear explosives requires: knowledge of the location of the target in space as a function of time, ability to resolve the target from its surroundings and the ability to deliver the warhead against it with a spatial error smaller than the destructive radius of the explosive charge. A weapon with a small kill-radius delivered with a great accuracy against a target would, in many cases, be the most cost-effective and efficient means of destruction. The probability of destruction of the target increases when either the error in delivery of the weapon is decreased (that is, increasing its accuracy), its destructive radius is increased or the number of weapons delivered against the target is increased. Increasing the delivery accuracy of a weapon is much more preferable to increasing the kill-radius of the weapon or the number of weapons delivered upon a target in terms of a net cost of a given capability. Increasing the kill-radius, that is, the yield, (this is especially true for conventional weapons) almost certainly

implies a greater increase of its mass and at the same time causes much more unnecessary collateral damage. Increasing the number of weapons delivered against a target requires a large number of delivery vehicles, personnel to control and service these vehicles, additional facilities for repair, transportation systems to deliver supplies and large numbers of these relative inaccurate weapons deployed to the theater of operation. Commensurate attrition rates of these support facilities caused by enemy action must also be included in the numbers planned. All these factors add up to a substantial economic penalty when considering the numbers of weapons required to provide an adequate deterrent posture. It is logical then that a weapon with a small destructive radius, delivered with great accuracy against a target, either mobile or stationary, would in most cases be both more cost effective and less randomly destructive than relatively inaccurate high-yield weapons delivered in large numbers.

High accuracy can be achieved either by allowing the missile to seek, recognize and home on its intended target or through providing it with accurate attitude, etc. Target recognition without human intervention, a desirable condition for a long-range weapon, is a challenging technical problem. The problem of accurate pre-programmed flight is only slightly less complex.

Thus, high accuracy delivery of weapons to a target is dependent on the development of reliable, light, miniature, relatively inexpensive electronic devices that can be mounted on a missile and which would typically occupy less than 20 per cent of the volume of the missile and about the same proportion of the useful payload.[7] As the operational range of the weapon is increased, the complexity and size of the electronic equipment needed for the guidance of the missile usually increases significantly. Increased size allows the accommodation of more elaborate electronic components required to maintain low missile track errors. These errors usually magnify as the range of the missile increases. If the target is not visually or instrumentally accessible from the point of launch, even more elaborate sensing and guiding equipment is needed, since recognition becomes much more difficult.

Having reviewed some key factors involved in accurately delivering weapons on targets, an examination will be made of the missile engine and guidance technology asymmetries which could enable the U.S. and U.S.S.R. to attain a LRCM countervalue strike capability.

a. Missile Power Plant Asymmetries

Power plant requirements needed to strike both counterforce and countervalue targets are different for

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[7]Stockhold International Peace Research Institute, <u>World Armaments and Disarmament SIPRI Yearbook 1975</u>, p. 314, <u>MIT Press</u>, 1975. (Henceforth known as <u>1975 SIPRI</u>.)

the Soviet Union and the United States. The U.S. requires longer ranged missiles to attain a strike capability. High efficiency engines are being developed to gain additional range without increasing the missile size. Small turbofan engine R&D and testing promise the potential of yielding a power plant capable of being installed in the HARPOON missile airframe. Replacing the HARPOON sensor system with a smaller guidance package will allow more fuel volume enabling longer engine burn time to obtain the projected 1500-2000 NM range.

The Soviet Union requires only half the range of the U.S. to attain an equivalent countervalue strike capability. The SS-N-3 cruise missile deployed aboard the ECHO-II class submarine has a range of approximately 550 NM.[8] The large size of the SS-N-3 missile (42 feet long)[9] and its turbojet propulsion system qualify it as a strategic cruise missile.[10] By comparison the proposed U.S. LRCM is 20.5 feet long including the booster. The large SS-N-3 missile size enables the Soviets the

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[8]Hotz, R., "Pitfalls of SALT-II," Aviation Week & Space Technology, v. 103, p. 9, 15 December 1975.

[9]See Appendix A.

[10]Aviation Week and Space Technology, "Shaddock-Armed Soviet Subs in Cuba," v. 103, p. 13, 24 November 1975.

"...capability to more than double...that range...by making relatively simple and undetectable propulsion and operational changes. With even their present range, the Shaddock can reach a large percentage of U.S. population centers and the bulk of U.S. industrial sinews, which are mainly in coastal belts."[11]

The SS-N-3 missile is an old design. Reasonably increased SS-N-3 performance capability projections can be made by comparing the size and perceived aerodynamic characteristics with current U.S. cruise missile and aircraft state-of-the-art technology. It is assumed that the Soviets can attain the same engine technology level if adequate resources are brought to bear.

A scaled comparison was made between the SS-N-3[12] the proposed U.S. strategic cruise missile,[13] and Northrop Aircraft Division F-5E Aircraft[14] line drawings. The F-5E was selected because, when scaled to 42 feet it more closely approximates the aerodynamic characteristic of the SS-N-3 than the U.S. strategic cruise missile. It is reasonable to assume that the Soviets would probably use the same

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[11]Hotz, op. cit.

[12]Pretty, R. and Archer, D., Jane's Weapon Systems 1974-1975, p. 54, Paultone House, 1975.

[13]U.S. Senate Hearings, op. cit.

[14]F-5E data was obtained from Northrop Aircraft Division Public Promotion Literature.

launcher platforms if they upgrade the SS-N-3 technology. It is also reasonable to assume they would probably use a missile which was similar in size to the SS-N-3 because it could be deployed on the same launcher possibly without any modification.

Scaling the volume and weight dedicated to various functions of the F-5E allows estimates of the SS-N-3 missile's weight, lift to drag (L/D) ratio and velocity for maximum range to be made. Scaling the weight of the F-5 aircraft less the landing gear, cockpit and other non-essential components, the SS-N-3 can be reasonably estimated to weigh about 10,000 pounds. Computing the wing area and comparing L/D ratios of other low wing-area aircraft (the F-105 has a L/D of about 9), a L/D ratio of 10 may be a reasonable estimate. Factoring in state-of-the-art engine, guidance, warhead and airframe technology, reasonable estimates can be made of the volume and weight ratios these components occupy. Electronic guidance components capable of placing warheads on countervalue targets with reasonable accuracy might typically occupy approximately 10% of the missile volume and about the same proportion of the useful payload.

The J-85-4A non-afterburning turbojet engines installed in the F5 aircraft occupy about 25% of the fuselage volume and about 20% of the aircraft weight. The J-85 specific fuel consumption (SFC) at mach .9 and at

36,000 feet is 1.22 pounds. SFC is the amount of fuel per hour of operation per pound of engine thrust the aircraft requires. A state-of-the-art low bypass ratio turbofan engine that would fit into the three-foot[15] diameter SS-N-3 missile might typically occupy 20% of the volume and 20% of the total weight of the missile. SFC rates for such an engine might be close to one operated at altitude and at maximum cruise range.

The body, wings and tail of the F-5 aircraft occupy about 30% of the weight of the aircraft. The F-5 is a high-performance aircraft though capable of withstanding high G forces throughout the life of the aircraft. The SS-N-3 would probably not be designed to as high a specification since the airframe is expendable. With the reduced performance requirements the airframe might typically occupy 20% of the total weight and about the same proportion of the volume.

The remaining factors which must be considered are the warhead and the fuel. Assuming the Soviets continue their policy of building missiles with high yields, a 1 MT warhead may be a reasonable size weapon the Soviets might employ in an upgraded SS-N-3 missile. "Current nuclear warhead technology permits the manufacture of small warheads with about one kiloton TNT equivalent yield per

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[15]Pretty and Archer, op. cit.

pound of warhead weight. Thus, a 200 KT warhead will weigh about 200 pounds."[16] Assuming that yield and weight scale proportionately, a 1 MT weapon would weigh about 1000 pounds, 10% of the weight of the missiles. It may be reasonable to assume that the warhead would not occupy more than 20% of the volume of the missile.

The projected weights and volumes of the component parts are listed in Table I. The remaining portions of the missile not already discussed are 40% of the weight and 30% of the volume which will be considered available for fuel. The SS-N-3 missile volume was estimated by considering its length to be 40 feet (decreased by two feet to account for fuselage taper) and having a three-foot diameter. Applying the cylinder volume equation $\pi r^2 L$, approximately 280 cubic feet are obtained.

JP-4 jet fuel weighs about 6.5 pounds per gallon and there are about eight gallons of JP-4 per cubic foot of volume. Eighty-four cubic feet of missile space would accommodate about 670 gallons. That amount of fuel would weigh about 4,350 pounds which is 350 pounds more than the total missile was estimated to weigh. For simplicity it will be assumed that the 350 pounds is distributed throughout the remaining missile components and the missile fuel capacity is 4000 pounds.

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[16] 1975 SIPRI, op. cit., p. 325.

TABLE I

Estimated Weight and Volume Parameters
of Possible SS-N-3 Follow-on

Component	% Wt.	# Wt.	% Vol.	Ft^3
Airframe	20	2000	20	56
Engine	20	2000	20	56
Guidance	10	1000	10	28
Warhead	10	1000	20	56
Fuel	40	4000	30	84
Totals	100	10,000	100	280

The J85 turbojet engine consumes about 1300 pounds of fuel per hour at mach .9 at 36,000 feet. A similar Soviet engine installed in the SS-N-3 would have sufficient fuel to operate approximately three hours. Three hours at even Mach .8 (about 430 MPH) would enable the missile to fly 1320 miles.

Analyzing the missile's performance capabilities using a turbofan engine and a different methodology, at subsonic speeds a cruise missile will approximately consume fuel in proportion to its weight and inversely proportional to its lift-to-drag ratio. Therefore, the fuel it will consume over the time T it takes to fly from launch to target is

$$\int \frac{dm}{dt} = \frac{M}{L/D} \times \mathrm{SFC} \qquad \text{(II-1)}$$

where SFC is the amount of fuel per hour of operation per pound of engine thrust the missile requires. Integrating over time (II-1) becomes

$$M_{fuel} = \frac{M}{L/D} \times (\mathrm{SFC}) \times T \qquad \text{(II-2)}$$

where M is the weight, but if the range of the missile is R and its velocity V

$$T = R/V \qquad \text{(II-3)}$$

Substituting (II-3) into (II-2) and rearranging the equation we have[17]

$$\frac{M_{fuel}}{M_{missile}} = \frac{R \times (SFC)}{L/D \times V} \qquad \text{(II-4)}$$

For a missile of L/D = 10, V = 0.8 Mach and SFC = 1 pound of fuel per pound of engine thrust per hour

$$\frac{M_{fuel}}{M_{missile}} = \frac{R \times 1}{10 \times 691} \qquad \text{(II-5)}$$

$$\frac{M_{fuel}}{M_{missile}} = 1.4 \times 10^{-4} \times R \qquad \text{(II-6)}$$

For the projected missile and fuel weights

$$(1.4 \times 10^{-4} \times 2.9 \times 10^{3} \text{ Km}) = .4$$

yielding an 1800-mile range capability. Fuel required to climb to cruise altitude must be subtracted from the total fuel weight, but that still makes the missile a very capable weapons platform.

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[17]1975 SIPRI, op. cit., p. 324.

Analyzing the data presented, it is reasonable to assume that the Soviets could modify the SS-N-3 missile and attain potential range capabilities that could enable them to strike most of the countervalue targets in the United States.

b. Missile Guidance Asymmetries

The U.S. requires longer missile ranges to attain a countervalue strike capability. Long-range missiles require a more elaborate guidance system to monitor and resolve accumulated track errors. Until recently, available electronics technology did not provide the means to direct long-range missiles with precision guidance. Recent advances in large-scale integration of microcircuits have made possible an entirely new set of micro-miniatured electronic devices. These developments have made possible the construction of guidance systems for long-range self-guided missiles with ranges that are now independent of guidance considerations.

Large-array microcircuits are electronic circuits fabricated on very thin substrates that contain on a few square centimeters the equivalent of many thousands of electronic logic circuits. Densities of a million devices (such as a photo-sensitive diode or a bipolar transistor) per square centimeter of substrate material that is 250 microns thick, are commonly achieved. Allowing for airspace, it is conceivable that a device can be built

that can store 10^8 bits of serially read-out information per cubic centimeter of electronic memory.[18]

The guidance and control of a missile requires many logic circuits and memory banks. The development of large-scale integration (LSI) has enabled practical realization of a navigation system which uses a new method for the accurate delivery of weapons over long ranges. This guidance principle, based on terrain matching and recognition, is known as Tercom.[19]

Tercom operates on the principle that the geographic location of any place on the earth is uniquely defined by vertical contours, or topography, of the surrounding area. Tercom requires previous mapping or other determination of the terrain contour characteristics for the area over which missiles are intended to fly.[20] Terrain contour data for an area over which a particular mission is to be flown are stored in the missile's Tercom computer. During an operational mission the Tercom system measures the vertical contour of the terrain along its flight path, using a radar or laser altimeter to measure clearance above the terrain and a barometric altimeter to provide a reference. By comparing the two altitude

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[18]Tsipis, K., "The Long Range Cruise Missile," Bulletin of the Atomic Scientists, v. 31, p. 17, April 1975.

[19]Klass, P. J., "New Guidance Techniques Being Tested," Aviation Week and Space Technology, v. 100, p. 48, 25 Feb. 1975.

[20]Ibid.

readings, one relative and one absolute, a single terrain evaluation is determined. Repeated measurements define the sequence of contours beneath the flight path. Comparison is then made with stored contours, of known coordinates, to determine that which closely matches the measured one. This procedure fixes the missile position relative to the coordinate system and can be used to update the missile's inertial system.

While the theory of Tercom is simple, the successful realization of a system is far more difficult. One of the key parameters for successful design involves considering the granularity, or resolution, with which the system attempts to measure and compare vertical profiles. This is called "cell size."[21] Another is the number of cell-size samples that are used at one time to establish the terrain contour along the vehicle flight path. The greater the number of samples, the more accurate the profile. But this increases the required computer capacity and time needed to search for a matching profile in memory.

For the system being currently developed, a match is sought between the measured contour and pre-stored ones, first behind and ahead of the missile's calculated position along the expected flight path. If this comparison fails, comparison is made with 4.9 mile-long contours

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[21]Klass, op. cit., p. 48.

both to the left and to the right of the vehicle's flight paths, both behind and ahead of estimated position.[22] The extensive data comparison requires sophisticated computational facilities. Thus, actualization of Tercom requires light-weight, low-cost, high-capacity computers made possible by LSI.

In addition to the Tercom system the vehicle needs to carry another navigation system, either inertial, Doppler or simple air-speed-heading type.

When Tercom has found the closest contour match and fixed the vehicle's position, this information is used to update the associated navigation system. Because Tercom operates by sensing and comparing terrain profile, it cannot be used to obtain position fixes over the ocean, large bodies of water, or marsh lands. The LRCM can use its conventional navigation system for guidance until it reaches landfall. This suggests the use of an inertial system. At landfall Tercom can update the inertial system. Periodic fixes and updates during the remainder of the mission produce high accuracy with a modest inertial system.

The accuracy demands imposed on the Tercom radar altimeter are not excessive, especially in terms of absolute accuracy, because the need is to measure the vertical profile of the terrain below rather than its absolute height relative

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[22] Klass, op. cit., p. 49.

to the vehicle. Typically, Tercom needs to determine the terrain elevation only to an accuracy of several feet.[23] Tercom performs most accurately when used in low-altitude flight, because the topographical contour can be measured more precisely. At higher altitudes, due in part to the beam width of the radar altimeter, there tends to be more averaging of the measured contour.

For the proposed LRCM, terminal guidance is performed with a passive radiometer. This device probably senses terrain reflectivity at one or more wave lengths to produce a form of image of the target area. Guidance is then accomplished by an image correlation technique. The combination of Tercom-aided inertial guidance and pattern-recognition terminal guidance permits accuracies under 30 meters at 1,500 NM ranges.[24] Both Tercom and terrain-recognition terminal guidance cannot be jammed effectively or inexpensively by electronic countermeasures. Although one could imagine methods for jamming the terminal guidance of the missile, they would be so costly and elaborate that they are not considered realistic.[25]

In summary the U.S. requires long missile ranges to attain a counterforce and countervalue strike

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[23]Klass, op. cit., p. 49.

[24]Tsipis, op. cit., p. 13.

[25]Tsipis, op. cit.

capability against the Soviet Union. The development of Tercom should provide accuracies far better than those attained by a preprogrammed autopilot guidance system in a missile operating over a 500-600 NM flight track.

Equivalent Soviet countervalue strike capabilities may be obtained with one half the missile range required by the U.S. since major U.S. cities and industrial areas are predominantly concentrated along the coastal regions. For many countervalue purposes, missile accuracies are less critical. Hence, less complex missile guidance systems are needed by the Soviets to gain similar countervalue probability of kill results. According to Janes[26] the SS-N-3 missile employs a preprogrammed autopilot guidance system and has a 550 NM range.

Guidance system improvements would probably be required should the Soviets upgrade the engine to state-of-the-art technology and more than double the present range.

Upgrading the present SS-N-3 guidance with a gyro-stabilized inertial system could probably provide increased capability. An inertial system detects errors in the desired flight path by measuring the lateral and longitudinal accelerations during missile flight. Accelerometers detect missile velocity changes without the need of an external reference. The acceleration signals are

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[26]See Appendix A for table.

fed to a simple computer which produces distance traveled indications. A gyro-stabilized platform is interfaced with the inertial system to detect errors in the pitch, roll, and yaw axis. Such systems have been developed for ballistic missiles which allow accuracies of fractions of a mile at intercontinental ranges. A similar level of technology could probably support accuracies of a few hundred feet at ranges of 1500 miles. Soviet inertial guidance technology gained through ICBM development is probably readily available for installation in the SS-N-3. Interfacing a basic Doppler navigation system with the inertial guidance could supply a backup system and provide the Soviets with a highly reliable countervalue capable missile with comparable functional capability to the proposed LRCM.

A composite guidance system employing a combination of sensors would also be a possible alternative for the SS-N-3. Long Range Navigation (LORAN) or radio beacon (commercial or navigation aids) homing techniques could be employed and extremely small CEPs gained. LORAN and radio beacon navigation aids are readily available along both U.S. coasts. Redundant coverage is available in most areas. An automatic LORAN receiver preset to a line of constant time difference (from a simultaneous pulsed station-pair) which crosses an intended target area could furnish accurate guidance information to the missile navigation system. Automatic direction finding

(ADF) receivers tuned to radio beacon frequencies could also yield very accurate navigation information. All major population centers have commercial radio stations and by employing terminal bearing measurement techniques, very accurate countervalue strike capabilities can probably be attained. OMNI and TACAN navigation systems captured in downed U.S. aircraft in Southeast Asia have probably been analyzed and duplicated by the Soviets. Installing either one of these systems in the SS-N-3 could provide a terminal precision navigation capability. Combining an inertial system with one or two of the aforementioned radio navigation aids through a matrix switch could provide a very accurate navigation system for the SS-N-3. Admittedly our navigation aids may be turned off during a national emergency so the Soviets could not utilize them. However, any crisis which resulted in the use of nuclear weapons against countervalue targets would probably be initiated by surprise by the Soviets and our navigation aids would be operational.

Soviet micro-miniaturization of electronic components technology is estimated to be five to ten years behind the U.S.[27] That factor does not mean that it will take the Soviets ten years to build and deploy a modified

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[27]Robinson, C. A., "Single Cruise Missile Set for Varied Use," Aviation Week and Space Technology, v. 102, p. 19, 24 February 1975.

SS-N-3 missile with a guidance system similar to Tercom. The SS-N-3 missile is more than twice the size of the U.S. LRCM (42 feet versus 20.5 feet); hence to obtain similar guidance technique capabilities, Soviet miniaturization technology does not require the refinement obtained by the U.S. to attain the same capability.

Employing a Tercom type system in the SS-N-3 missile would probably not be cost-effective for the Soviets. Effective countervalue strikes can be obtained without employing this state-of-the-art technology. Should the Soviets upgrade the missile engine with more recent turbofan technology and attain projected ranges of approximately 1500 NM, any combination of the guidance systems discussed would probably furnish effective countervalue strike capabilities to these ranges. However, since approximately 50% of U.S. population is concentrated within 150 NM of the coasts, unacceptable damage can be inflicted without increasing the range or guidance accuracy of the SS-N-3 missile. Soviet air-surface cruise missiles carried by long-range refuelable aircraft have similar capabilities and should be considered as an equally serious threat. See Appendix A for Soviet air-surface cruise missiles, their performance characteristics and their launch platforms.

B. STRATEGIC ASYMMETRIES

1. Strategic Targeting Asymmetries

The fundamental elements of nuclear strategy can probably be reduced to an analysis of the interaction between alternative targeting options and alternative capabilities for threatening, destroying or protecting those targets. This applies to highly elaborate deterrence or war-fighting strategies based on possession of a wide variety of nuclear weapons with different performance characteristics or, alternatively, to very simple strategies based upon the ability to deliver one nuclear weapon one one city with a simple strategic weapon like a long-range cruise missile. An analysis of basic strategic targets is important because recent developments in weapons accuracies at both the tactical and strategic levels have enhanced the importance of identifying and classifying specific targets into categories according to their susceptability of being attacked by ballistic missiles, cruise missiles and bombers. The primary advantage of accurate weapons systems is that they can be used with fairly low yields against selected targets in populated areas while minimizing collateral damage to civilian populations. The proposed U.S. LRCM will have this potential capability to strike non-time sensitive targets. The ability to target precisely a whole array of industrial, as well as military targets with different types of weapons enables flexibility in

obtaining foreign policy objectives and provides the decision maker with the necessary decision space to obtain those objectives.

Targets can be categorized as counterforce and countervalue targets. Counterforce targets have military significance, usually associated with forces or installations, and countervalue targets are usually major population and industrial centers. Counterforce targets include: hardened ICBM silos; bombers and their bases; ICBMs not in hardened silos; submarines in port; air defense and ABM systems; command and control centers; nuclear stockpiles; nuclear production facilities; military bases and staging areas; and ammunition and fuel dumps.

Countervalue targets include: population centers; industrial structures and facilities; raw materials and energy production; missile and aircraft factories; gaseous diffusion plants; and transportation and communications facilities.

The aggregate size of a country's population has important military and strategic implications. Population distribution and composition are also important in terms of strategic nuclear warfare. Population distribution indicates what percentage of the nation resides in urban and rural areas, and which urban and rural areas are the most densely populated. Industry is usually collocated near urban centers making these targets high on the countervalue target

list. Facilities associated with the production, refining and distribution of petroleum, natural gas and coal; and hydro-electric, thermal and atomic power stations and transmission networks are also high economic value targets.

For various historical, economic and political reasons the Soviet Union is a nation with a great many large high-density cities. According to the 1970 census she had 201 cities of over 100,000 people[28] as compared to the U.S. which has 216 cities over 100,000 inhabitants and, despite her large goegraphic area, the majority of the population is located in less than a quarter of the country's total area. According to the 1970 census, the Soviet Union has 250.9 million people and approximately 56 per cent are classified as urban dwellers. Of this urban population, approximately 70 per cent are in European Russia, west of the Urals. Approximately 35 per cent of the total Soviet population and 60 per cent of the urban population, resides in 310 cities with populations in excess of 50,000. While it is important to know the total size and composition of Soviet population and industry, it is also important to know their distribution throughout the country and, from the point of view of targeting specific areas, to have some indication of the population density of various metropolitan areas. Appendix B lists all Soviet cities with populations over

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[28]See Appendices B and C.

100,000, their density, area covered, and potential warhead requirements.

The geographic location of the major cities is a vital vector when considering targeting alternative weapons systems having different ranges or launched from different firing positions. The most heavily urbanized regions (by percentage of population living in large cities) are, in this order: Northwest, Central, Western Siberia, Donets-Dnepr, and Urals and Volga.[29]

The most salient targeting asymmetry is the distance from reasonably secure weapon launch positions to counterforce and countervalue targets. Approximately 50 per cent of the U.S. population is concentrated in cities greater than 100,000 inhabitants within 350 NM of the coasts[30] (within range of the present SS-N-3) as compared to the Soviet Union where the easternmost major city, Leningrad, is roughly 1000 NM from a reasonably secure launch position; assuming a 200 NM buffer launch zone to avoid coastal surface anti-submarine warfare efforts and extended Soviet air defense along the North and Berents Sea coast areas. Long-range cruise missiles may not have the range to strike all counterforce and countervalue targets, but are capable of striking a significantly large proportion to make it a formidably capable strategic weapon system.

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[29]Harris, C. D., <u>Cities of the Soviet Union</u>, Rand McNally, p. 16, 1970.

[30]See Appendix D.

Sufficient numbers of SS-N-3s launched from E-II submarines, surfaced 200 NM off either coast, could inflict significant damage to U.S. counterforce and countervalue targets. Counterforce targets within the range of the SS-N-3 include: submarines in port; submarine missile storage areas; bomber bases within range of the coast; nuclear power plants; national command center, i.e., President and his staff; naval bases; military bases and staging areas; airfields; ammunition and fuel dumps; and air defense systems. Countervalue targets include: industrial structures and facilities; population centers; missile and aircraft factories; gaseous diffusion plants; transportation and communications facilities; plus many additional facilities too numerous to mention. The U.S. forward base system (FBS) is very vulnerable to attack by submarine launched, surface launched, and air launched cruise missiles. The SS-N-3 launched from the KYNDA cruiser has a range capability of 250 NM, the AS-6 launched from the "BADGER Modified" and possibly BACKFIRE bombers is assessed as having a 300 NM range capability, and the modified AS-4 launched from the BACKFIRE B is assessed as having a 425 NM range capability.[31] Expanding world-wide Soviet naval exercises demonstrate the increased emphasis the Soviets are placing on naval power, enhancing their capability to

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[31]See Appendix A.

strike the U.S. FBS. The only major counterforce targets the SS-N-3 would not be capable of striking are ICBM silos and bombers and their bases deployed inland from the coastal areas. Combining the overwhelming number of vulnerable targets with the lack of air defense capability to detect low-flying targets, the SS-N-3 missile, if used in a strategic mode, poses a very serious threat to the United States. Soviet air-surface cruise missiles carried on long-range bombers have similar capabilities and should be considered as an equally serious threat.

United States cruise missile targeting problems are much more complex than those of the Soviets due to geographical differences. Increased range is required to strike most targets. Coastal counterforce targets, for the most part, are nearly 1000 NM from safe launching zones. Limited numbers of counterforce targets like Northern and Pacific Fleet naval installations and early warning facilities can be targeted at ranges less than 1000 NM. Most countervalue targets are located at ranges from 1000 to 2000 NM from safe launch zones.[32]

Soviet major cities are more dense than U.S. cities, but only 10 major cities have populations greater than one million as compared to the U.S. which has 33 cities with populations greater than one million. On balance, the

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[32]Kemp, G., "Nuclear Forces for Medium Powers: Part I, Targets and Weapon Systems," Adelphi Papers No. 160, p. 8-11, IISS, 1974.

Soviet Union is more rural than the United States. Thirty per cent of the Russian people live in cities having populations greater than 100,000 inhabitants as compared to the U.S. where 64% of the total population live in cities having more than 100,000 inhabitants. From this data it is obvious that the Soviets have a relatively simple potential targeting problem as compared to the U.S. which must possess longer range missiles having more highly accurate guidance systems. Since the Soviet Union is more rural and the urban areas much smaller than the U.S. it is evident that potential targeting for casualties greater than 25% of the population would require increasingly larger numbers of weapons.

The Soviet Union could potentially inflict 50 million casualties (25% of the U.S. population) by striking approximately 70 cities within 350 NM of the coast with about 150 one-MT warheads.[33] To account for failures due to launch, guidance, warheads, etc., and considering the Soviets' policy of using large numbers of weapons, the Soviets could probably dedicate a minimum of 200 one-MT warheads to inflict that potential damage (see Table XII). The Soviets have 280 SS-N-3 missiles deployed on ECHO-II and JULIET submarines and an additional number of air-surface cruise missiles, having ranges from approximately 300 to 400 NM deployed

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[33]See Appendix E.

on the BEAR B and C and BADGER MODIFIED which could be deployed against the U.S.[34] Assuming the Soviets upgrade the SS-N-3 engine, guidance and warhead to a one-MT weapon, these weapons alone could inflict unacceptable damage on the United States.

2. Air Defense Asymmetries

The LRCM poses a challenge to present early warning systems and air defense forces in both the U.S. and the U.S.S.R. The total air defense capability of the U.S.S.R. is enormous--far in excess of that of any other country. Detailed information on the Russian air defense systems is not readily available in open-source literature; however, it is estimated that the U.S.S.R has around 10,000 surface-to-air missile launchers and thousands of air defense radars to go with them.[35] In addition to an effective early warning detection system, the Soviets have an extensive fighter-interceptor capability to defend their coastal territory from penetrating aircraft. The U.S. does not possess the numbers of early warning detection systems, surface-to-air missile launchers and fighter-interceptors possessed by the U.S.S.R. Consequently, the probability of detection and destruction of large numbers of similar airborne targets is lower in the U.S. than in the U.S.S.R.

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[34]See Appendix A.

[35]Pretty and Archer, op. cit., p. 219.

The LRCM will pose a unique problem for the Soviet defense system. Radar cross-section reduction efforts have decreased the U.S. LRCM radar return to the size of a seagull and using radar absorption material, it is being attempted to decrease the radar cross-section down to the size of a sparrow.[36] Current air defense radars are probably not capable of detecting and tracking such targets. New radars or other types of sensors capable of operating against a low-altitude small radar cross-section target will probably have to be developed. Clutter problems experienced at low grazing angles create signal processing difficulties, making low level target detection and tracking extremely complex. Similar problems are encountered in designing low altitude surface-to-air missile guidance systems.

3. Asymmetries in Essential Equivalence

The objective of essential equivalence is based on the desire to match Soviet counterforce and countervalue capability and prevent the Soviet Union from attaining meaningful numerical superiority in strategic forces, namely: numbers of delivery vehicles, types of delivery vehicles, numbers of deliverable warheads and total deliverable megatonnage (throw weight). Strategic weapons programs can be said to demonstrate technological pre-eminence, a

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[36]U.S. Senate Hearings, op. cit., p. 5131.

determination not to relinquish the initiative on the stage of world politics, and continued American resolve in the pursuit of our various foreign policy objectives. Essential equivalence is also viewed as an intention to reduce the likelihood of confrontation and crisis by dissuading Soviet leaders from believing that their superiority in nuclear weaponry is exploitable diplomatically or militarily.

When the SALT I agreement was signed in May, 1972, one of the principal criticisms of the accords was the great disparity in throw weight between the U.S. and U.S.S.R. ICBM's. This lack of equivalence was feared to provide the Soviets with a potential first strike capability against U.S. land-based strategic forces in the long term. Operational U.S. and Soviet strategic forces and their characteristics in May, 1972, are presented in Table II.

Strategic missile forces deployed by the U.S. and U.S.S.R. in July, 1975, are presented in Table III.

In addition to state-of-the-art ballistic missiles, the Soviets have cruise missiles deployed on submarine, surface and airborne platforms.[37] Deploying cruise missile launch platforms to politically sensitive areas enables the Soviets to demonstrate resolve and enhance their foreign policy objectives. Nuclear warhead yields carried by Soviet long-range cruise missiles are small compared to "total"

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[37]See Appendix A.

TABLE II

Operational U.S. and Soviet Ballistic Missile

Forces, May 1972[38]

Soviet Ballistic Missiles

System	Throw Weight (lbs)	No. of Warheads	Yield
SS-7	3000-4000	1	5MT
SS-8	3000-4000	1	5MT
SS-9	12000-15000	1	20-25MT
		3	5MT
SS-11	1500	1	1-2MT
		3	100-300KT
SS-13	1000	1	1MT
SS-N-4	1500	1	1-2MT
SS-N-5	1500	1	1-2MT
SS-N-6	1500	1	1-2MT

U.S. Ballistic Missiles

MM-1	1000	1	1MT
MM-II	1000	1	1MT
MM-III	2000	2-3	170KT
TITAN II	7000-9000	1	9-10KT
POLARIS A-2	1000	1	800KT
POLARIS A-3	1000+	3	200KT
POSEIDON	2000-3000	6-10	40KT

[38]Schneider, M., "SALT and The Strategic Balance, 1974," Strategic Review, U.S. Strategic Institute, p. 42, v. 2, Fall 1974.

TABLE III

Strategic Missile Forces Deployed

by the U.S. and U.S.S.R.: July 1975[39]

U.S.S.R. Missiles

Missile	Warhead Yield (MT)	CEP[40]	Re-entry Vehicles	No. Missiles	Total Throw Weight (MT)
SS-9	20-25	(1)	1	288	7200
SS-11 SS-13	1-2	(1)	1	970	1940
SS-13	1	(1)	1	60	60
SS-N-6	1	(1-2)	1	528	528
SS-N-8	1	(1-2)	1	80	80
SS-7 SS-8	5	(1.5)	1	209	1045
TOTALS				2075	10,853

U.S. Missiles

Missile	Warhead Yield (MT)	CEP	Re-entry Vehicles	No. Missiles	Total Throw Weight (MT)
MM-III	.16	.2	3	550	264
MM-II	1	.3	1	450	450
TITAN	5	.5	1	54	270
POLARIS	.05	.3	10	496	248
POSEIDON	.20	.5	3	160	96
TOTALS				1710	1328

Note: Numbers in parentheses are estimates.

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[39]Estimated warhead yields, re-entry vehicles and no. missiles obtained from The Military Balance 1974-1975, p. 69, IISS 1974.

[40]CEP data obtained from Tsipis, K., "The Accuracy of Strategic Missiles," Scientific America, v. 233, p. 21, July 1975. Many observers feel that the Soviet missiles have accuracies 2 to 4 times better than the values cited by Mr. Tsipis.

ballistic missile throw weight yields, but utilizing these missiles as a threat against third-world countries and as a secondary weapon against U.S. or allied targets makes the cruise missile a formidable weapons system which must be considered in the strategic arena. The Soviets have been developing a cruise missile capability since 1958 and recent open-source literature indicates that the Soviets are developing a new submarine-launched nuclear tipped cruise missile and a new air-launched nuclear tipped missile.[41]

The Soviets presently have SS-N-3 SHADDOCK cruise missiles deployed aboard ECHO II, JULIET, and older WHISKEY submarines; and KYNDA and KRESTA I cruisers.[42] Twenty-seven ECHO-II and 16 JULIET submarines can carry 280 cruise missiles (see Table IV). The SS-N-3 missile has been operational since 1961-62. This missile has a current range of about 550 NM, with a capability to probably double that range by making relatively simple propulsion and operational changes.[43] The SS-N-3 reconfigured could probably fly a trajectory that would enable it to strike cities in the Midwest.[44] The Soviets have been operating ECHO-II

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[41]See Appendix A.

[42]Ibid.

[43]Hotz, R., "Pitfalls of SALT-II," Aviation Week and Space Technology, v. 103, p. 9, 15 December 1975.

[44]"Soviets Press Sub Operations at Cuba," Aviation Week and Space Technology, v. 103, p. 18, 15 December 1975.

TABLE IV

Operational U.S. and Soviet Cruise Missiles

Soviet Cruise Missiles[45]

System	Launch Platform	Launchers	No. Launchers	No. of Missiles	(MT) Yield[46]	Total Yield (MT)
SS-N-3	27 ECHO-II	8	216	280[47]	.05	14
	16 JULIET	4	64			
AS-3	20 BEAR B & C	2	40	40	.05	2
AS-4 Modified	BACKFIRE B	2			.05	
AS-6	50 BADGER Modified Bombers	2	100	100	.05	5

U. S. Cruise Missiles

NONE	NONE

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[45] See Appendix A. Table IV lists cruise missiles having the greatest strategic potential.

[46] An estimate; <u>The Military Balance 1974-1975</u>, p. 69, lists missile having yield in KT range.

[47] Totals include only ECHO-II and JULIET Submarine launchers.

class submarines in Cuban waters probably as part of a political-military probe of U.S. resolve.[48]

The Soviets have a submarine facility in Cienfuegas Harbor and maintain a submarine rescue vessel from other ports in Cuba.[49] The first ECHO-II submarines called at the port of Antilla from May 27 through June 4, 1971 and were accompanied by a tender.[50] Since that time, five other ECHO-class submarines have called at Havana and Cienfuegos.[51] Since 1969, a total of about 30 Soviet submarines have called at Cuban ports.[52] These demonstrated cruise missile submarine operations from Cuban ports indicate the Soviets' capability and possible intentions to utilize these forward based facilities to obtain foreign policy objectives. These Soviet objectives could possibly include an attack on U.S. cities following a pre-emptive first-strike by ICBMs and SLBMs. Soviet air-launched cruise missiles pose a similar threat and should be included with submarine launch cruise missiles when equating U.S. and Soviet forces essential equivalence.

The major portion of the U.S. strategic megatonnage is deployed in the strategic bomber, compared to the Soviets

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[48]Robinson, op. cit., p. 14.

[49]"Soviets Press Sub Operations at Cuba," op. cit.

[50]Ibid., p. 18.

[51]Ibid.

[52]Ibid.

who have their major portion deployed in strategic missiles. Soviet bombers carry only one-fifth the megatonnage U.S. bombers carry (see Table V), making their bomber force strategically less critical and their throw weight potential less vulnerable to attack.

Soviet ballistic missiles carry eight times as much megatonnage as U.S. ballistic missiles (see Table VI), resulting in a significant asymmetry.

The SALT accords granted the Soviets 1,618 ICBM's compared to 1,054 for the U.S. The Soviets were granted 740 SLBM's with the option to build up to 950 in exchange for 210 of their older ICBM's. The United States was limited to 656 SLBM's with an option to build up to 710 in exchange for 54 TITAN II ICBM's.[53] The throw weight implicitly allowed the Soviet Union was reportedly four times that of the United States. Proponents of the SAL I accords argued that the Soviet advantages in numbers and throw weight were compensated by U.S. advantages in number of warheads, missile accuracy, numbers of bombers and tactical aircraft in Europe. However, the Soviets had 650 medium bombers and approximately 700 medium or intermediate-range ballistic missiles the U.S. was not counting since they do not pose a threat to the continental U.S. However, they are a threat to our European allies.

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[53]The interim agreement and protocol signed at Moscow May 26, 1972, with agreed interpretations, common understandings, and unilateral statements, are contained in Appendix G.

TABLE V

Operational U.S. and Soviet Strategic Bombers[54]

Soviet Bombers

System	A/C	Yield (MT)[55]
BISON	40	
BEAR	100	
BADGER	500	
TOTALS	640	3,600

U.S. Bombers

B-52	360	
FB-111	70	
TOTALS	430	16,500

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[54] The Military Balance, 1972-1973, p. 2, IISS, 1972.

[55] Yields are totals for all aircraft.

TABLE VI

U.S. and U.S.S.R. Throw Weight[56]

U.S.S.R. Forces

System	No. of Missiles/Platforms	Total Weight (MT)
Ballistic Missiles	2075	10,853
Cruise Missiles	420/113	21
Bombers	640	3,600
TOTAL		14,474

U.S. Forces

System	No. of Missiles/Platforms	Total Weight (MT)
Ballistic Missiles	1710	1328
Cruise Missiles	0	0
Bombers	430	16,500
TOTAL		17,828

[56]Throw weights are compiled from data in Tables III, IV and V.

Many of the assumptions upon which the Interim Agreement was based were proved faulty within six months of the signing. The Soviets proceeded developing a new family of ICBM's having improved accuracy and greater throw weight. The Soviets tested the SS-11 with a 2500-pound throw weight and three warheads-MRV's. The SS-N-8, assumed capable of throwing a 1500-pound payload about 2500 NM, was actually tested over 4,000 NM. By May 1974, the Soviets had four new ICBM's in an advanced testing stage. Three systems were considered large missiles. The SS-17 and SS-19 have three to five times the throw weight of the older SS-11. The SS-18 throw weight is thirty per cent greater than the SS-9, their largest deployed ICBM.[57] It should be noted that the SS-9 throw weight is already about ten times the payload of the U.S. MINUTEMAN ICBM. The SS-17 and SS-19 re-entry vehicles have a better accuracy than the older Soviet systems listed in Table III.

The SS-17 has been tested with four warheads and the SS-19 with six. The SS-18 has been tested with five to eight relatively large warheads. The SS-17 and SS-18 have also been tested with single RVs of very large size. The SS-18 is assed to have a hard target kill capability in its MIRV Version. The SS-17 already has such a capability

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[57]Report of the Secretary of Defense James R. Schlesinger to the Congress on the FY 1975 Defense Budget and FY 1975-1979 Defense Program, March 4, 1974, p. 45-47. (Henceforth known as 1974 Posture Statement.)

in its single warhead variant. It is expected that the SS-17 and SS-18 MIRV systems will achieve the accuracy needed to destroy hard targets.[58] When these new missiles are fully deployed, the Soviet ICBM force alone will carry 7000 to 8000 MIRVs with an average yield of one to two megatons. This is more than the combined U.S. ICBM force and SLBM force in terms of numbers of RVs and with six to twelve times the yield of the largest U.S. MIRV.[59] The most impressive feature of the new family of Soviet missiles is the potential for approximately tripling the already massive throw weight capability of the 1972 Soviet ICBM force. This emerging throw weight expansion coupled with an estimate of 500 to 700 meters CEP accuracy led Defense Secretary Schlesinger to conclude that the Soviet strategic weapons buildup will pose a substantial first-strike threat to hardened U.S. land-based ICBMs by the mid-1980s.[60]

Killing counterforce hard targets like ICBMs requires missiles that are capable of delivering warheads with great accuracy. "It is this feature of the new Soviet ICBM program which, with multiple high-yield warheads, translates into a potential hard target capability,

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[58] 1974 Posture Statement, p. 45-46.

[59] Ibid.

[60] Simmons, H., "SALT II Problems and Prospects," International Defense Review, p. 2, August 1975.

unmatched by the U.S.," according to Secretary of Defense Rumsfeld. "As the Soviets proceed with their expected ICBM deployment and continued improvements in accuracy, the combination of increased throw weight, MIRVing and improving accuracy will increasingly threaten the survivability of the fix-based MINUTEMAN force."[61]

This potential asymmetry was discussed in recent congressional hearings. "The U.S. currently has deployed 1,054 MINUTEMAN and TITAN ICBM silos. In a hypothetical counterforce attack the Soviets, using only their heavy ICBM missile force (i.e., 308 MIRVed SS-18s), could target two RV's to each U.S. silo. The effectiveness of the attack would depend on the hardness of the U.S. silos and the accuracy of the Soviet missiles. Assuming hardness values consistent with the upgraded MINUTEMAN silos, the following results could be expected:

Soviet CEP (NM)	Percent of U.S. silos destroyed
.25	59
.20	83
.15	95
.10	98

The heavy missile force is considered destabilizing since, as shown above, it has the potential of placing at risk

[61]Robinson, C. A., "Soviets Make New SALT Bid," Aviation Week and Space Technology, v. 104, p. 14, 2 February 1976.

a large portion of the U.S. silo-based force while allowing the Soviets to retain all of their SS-11, SS-16, SS-17, and SS-19 ICBMs in tact. This residual capability represents approximately two and one-half times the total throw-weight-potential of the U.S. ICBM force before the attack."[62]

Increasing re-entry vehicle accuracies will greatly increase their weapon lethality capability. Lethality of a weapon against a hardened counterforce target is a function of the warhead's yield and accuracy. Counterforce lethality can be expressed as follows:[63]

$$\mathrm{CMP} = \frac{Y^{2/3}}{(\mathrm{CEP})^2}\, n$$

where counter military potential (CMP) is an expression of the lethality, Y is the yield in MT, CEP is the accuracy in NM and n is the number of warheads. By inspection it is evident that as the CEP is decreased, the lethality is increased and the probability that the warhead can destroy a hard target is increased. Lethality increases much more rapidly with an improvement in accuracy than with an increase in yield.

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[62]Hearings before the Committee on Armed Services, House of Representatives, Ninety-fourth Congress, First Session, Overall National Security Programs and Related Budget Requirements, December 3, 4, 5, 8, 9, 10, 15, 16, 17 and 18, 1975, p. 247. (Henceforth known as Congressional Security Hearings.)

[63]See Appendix E.

Equivalent megatonnage (EMT) is an expression of a country's countervalue force potential. EMT can be expressed as follows:[64]

$$EMT = Y^{2/3}n$$

where Y is the yield and n is the number of warheads. Unlike CMP, the warhead accuracy is not a factor in determining the equivalent megatonnage; because accuracy is not critical when striking countervalue targets. Large yields increase a country's EMT. Yield times the number of warheads in a country's force provides a measure of the potential countervalue capability.

It is plausible that the Soviet Union and the United States may deploy ballistic and cruise missiles in numbers as listed in Tables VII, VIII, and IX. Open-source literature indicates that Soviet Design Bureaus remain functional as a unit after weapon models reach the production stage. These bureaus then start developing a follow-on weapon system. Considering this design philosophy, it is reasonable to assume that a new follow-on naval ballistic missile will be developed. It is also reasonable to assume that missile accuracies will approach those listed in the Congressional hearings.[65]

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[64] See Appendix E.

[65] Congressional Security Hearings, op. cit.

TABLE VII

Possible Mid-1980's Ballistic Missile Counterforce Potential[66]

Missile	MT[67]	CEP[68]	$Y^{2/3}$	CEP^2	CMP	# RV's[69]	CMP/Missile	# Missiles[70]	ΣCMP
U.S.									
MM-III	.20	.15	.34	.02	15.2	3	45.6	550	25,080
MX	.20	.15	.34	.02	15.2	10	152	450	68,399
POSEIDON	.05	.15	.14	.02	6.0	10	60.3	496	29,920
TRIDENT	.05	.15	.14	.02	6.0	10	60.3	312	18,814
								Total	142,213
U.S.S.R.									
SS-18	1	.15	1	.02	44.4	10	444	320	142,080
SS-19	3	.15	2.08	.02	92.4	3	277.2	1000	277,200
SS-N-6	1	.5[71]	1	.25	4.0	1	4.0	540	2,160
SS-N-8	1	.5	1	.25	4.0	1	4.0	252	1,008
NFO[72]	1	.15	1	.02	44.4	3	133.2	96	12,787
								Total	435,235

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[66]Plausible weapons deployment.

[67]Nacht, M., "The Vladivostok Accord and American Technology Options," Survival, The International Institute for Stragetic Studies, v. 17, p. 111, May/June 1976.

[68]Postulated from Congressional Security Hearings, op. cit.

[69]Estimated.

[70]Estimated.

[71]Simmons, op. cit.

[72]New follow-on Naval Missile.

TABLE VIII

Possible Mid-1980's Ballistic Missile Countervalue Potential

Missile	Yield MT	$Y^{2/3}$	# RV's	EMT/Missile	# Missiles	EMT
U.S.						
MM-III	.20	.34	3	1.02	550	561
MX	.20	.34	10	3.4	450	1530
POSEIDON	.05	.14	10	1.4	496	694
TRIDENT	.05	.14	10	1.4	312	437
						3,222
U.S.S.R.						
SS-18	1	1	10	10	320	3200
SS-19	3	2.08	3	6.24	1000	6240
SS-N-6	1	1	1	1	540	540
SS-N-8	1	1	1	1	252	252
NFO	1	1	3	3	96	288
						10,520

TABLE IX

Possible Mid-1980's SLCM Counterforce Potential[73]

Missile	Yield MT	CEP	$Y^{2/3}$	CEP^2	CMP/Missile	# Missiles	Total CMP
U.S.							
SLCM	.02[74]	.016[75]	.074	.00025	288	1000[76]	288,000
U.S.S.R.							
SS-N-3 Follow-on	1[77]	.15	1	.022	44.4	280[78]	12,444

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[73]Plausible weapons deployment.

[74]1975 SIPRI, op. cit., p. 325.

[75]Tsipis, op. cit.

[76]Estimated.

[77]Estimated.

[78]Assuming a SS-N-3 follow-on is deployed in ECHO-II and JULIET submarines.

TABLE X

Possible Mid-1980's SLCM Countervalue Potential

Missile	Yield MT	$Y^{2/3}$	EMT/Missile	# Missiles	Total EMT
U.S.					
SLCM	.02	.07	.07	1000	70
U.S.S.R.					
SS-N-3 Follow-on	1	1	1	280	280

Postulated U.S. and U.S.S.R. ballistic missile deployment, as listed in Tables VII and VIII, would gain the Soviets a three-to-one advantage over the United States in both counterforce and countervalue potential.

Deploying the SLCM, as listed in Table IX, would decrease the CMP asymmetry "gap" and decrease the potential strategic instability.

IV. STRATEGIC IMPLICATIONS

A. DETERRENCE

1. Theory of MAD

It is difficult to overemphasize the psychological aspect of deterrence. J. D. Singer[79] and the American behaviorist school define the perception of a threat as the product of the estimated capability of the opponent's forces multiplied by the estimated probability that he will use them. If there is no apparent intention to use force, even when a formidable force is available, there obviously is no threat. This century has seen startling changes in the relative strengths of offense and defense. World War II demonstrated the superiority of the defense overcome by using armor and close air-support aircraft. Carrier strike forces sank enemy fleets right in their own harbors, and amphibious forces successfully assaulted strongly defended coasts, while bombers inflicted heavy punishment on cities. Strategic offense matured in the 1950's and 1960's as nuclear weapons were further improved and long-range ballistic missiles were developed. Today a country contemplating an attack against another opponent which is armed with modern strategic offensive weapons is probably

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[79]Singer, J. D., "Threat Perception and the Armament-Tension Dilemma," Journal of Conflict Resolution, v. 2, p. 90-105, February 1958.

less concerned with the success of his own offense than with the potential capabilities of the adversary's offense. Here lies the crux of deterrence, the fear of the opponent's retaliation.

Deterrence can be considered a concept of foreign policy management that merges our force planning and employment considerations and fosters barriers to escalation, while affording rational alternatives at ever-lessening levels of conflict.

The dominant deterrence concept in contemporary strategic thought has been "mutual assured destruction" (MAD). The imperatives of the MAD concept have played an important role in our force planning assumptions, the design of our nuclear and conventional armed forces and in our arms control negotiations. We began to rely primarily on the ability to inflict damage, or "assured destruction," on the U.S.S.R. with our bomber force, and later our missile force, in order to deter the initiation of nuclear war or other large-scale aggression and thereby obtain "optimum" damage limitation. As Soviet nuclear forces became stronger, the mutuality of deterrence through assured destruction became more apparent. Deterrence through assured destruction as a U.S. policy was developed and promoted during the early middle 1960's by Secretary of Defense McNamara and others.

The MAD concept as implemented consists of a triad of sufficient strategic nuclear delivery forces (land-based ICBM's, submarine-launched ballistic missiles (SLBM's), and long-range heavy bombers) to inflict unacceptable damage on an aggressor, even after absorbing a counterforce first-strike from the aggressor.[80] "Unacceptable damage" has been generally defined for computational and explanatory purposes as substantial damage to industrial capacity (e.g., 25 per cent destruction from blast effects alone), and substantial urban population deaths (e.g., the prompt death of one-fourth to one-third of all urban population).[81] Fear of other nuclear effects, both physical (fallout) and psychological (mass hysteria), is presumed to contribute to deterrence. MAD relies on each side believing that such substantial damage to manufacturing plants and the death of many millions of people would destroy the viability of a nation as a modern society, and that recognition of these circumstances would deter the decision maker on each side from initiating any nuclear strike.

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[80]Kahan, J. H., "Stable Deterrence: A Strategic Policy for the 1970's," ORBIS, v. 15, p. 528-543, Summer, 1971.

[81]Statement of Secretary of Defense McNamara before a Joint Session of the Senate Armed Services Committee and the Senate Subcommittee on Department of Defense Appropriations on the Fiscal Year 1968-1972 Defense Program and 1968 Defense Budget, Washington: U.S. Government Printing Office, 1976.

2. Scales and Theory of Counterforce

The MAD concept has resulted in a relatively stable deterrence strategy for the past 20 years. However, during recent years there has evolved a widespread and deep-seated dissatisfaction with many of the fundamental premises underlying American strategic weapons policy. This dissatisfaction has originated in part from disappointment with the terms of the arms-control agreements concluded between the United States and the Soviet Union at the Moscow summit meeting in May, 1972. The Interim Agreement on Strategic Offensive Weapons is faulted for conceding numerical superiority to the Soviet Union. It also stems from the vigorous strategic weapons programs the Soviets are undertaking. This discontentment has provided the context for a new debate over the size and structure of the nation's nuclear forces.

In news conferences on 10 and 24 January 1974 and in testimony before Congressional committees,[82] Secretary of Defense James Schlesinger announced changes in the plans for U.S. strategic forces. These plans contain the intent of the United States to develop a much wider range of strategic options than were available in the past, and the intent to maintain rough symmetry in counterforce capabilities

[82]The International Institute for Strategic Studies, Survival, "Flexible Strategic Options and Deterrence," v. 16, p. 86-90, March/April 1974. (Henceforth known as Schlesinger's News Conference.)

with the Soviet Union, including the ability to destroy "hard" targets like ICBM silos. Secretary Schlesinger emphasized that the U.S. target plans under the MAD strategy had included only a few options, all of which involved a large number of weapons and targets. The new targeting plans would provide the President with different options and flexibility to strike fewer targets if circumstances dictated. These announcements have sharply increased the debate of strategic counterforce doctrine and its implications.

Counterforce is the strategy of attacking the adversary's military forces as contrasted with countervalue, which is the strategy of attacking the adversary's targets of high economic or human value including: cities, factories, energy sources, transportation choke points, etc. Three levels of counterforce strategy have been debated: disarming first-strike, damage-limiting counterforce, and restrained counterforce.[83]

Disarming first strike consists of a counterforce attack sufficient to reduce the adversary's total retaliatory capability to a level one considers tolerable.[84]

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[83] Sherman, R., "The Fallacies of Counterforce," Strategic Review, v. 3, p. 48, Spring 1975.

[84] Ibid.

A tolerable level was documented earlier in this study.[85] A disarming first strike against an adversary's ICBM's, for example, may not be a rational option because of the victim's capability to retaliate and destroy the aggressor's society by means of SLBMs and manned bombers. This strategy assumes that sea-launched nuclear weapons are now, and will be for the foreseeable future, essentially invulnerable at sea, and that these forces will comprise a large portion of each side's nuclear weapons. Damage-limiting counterforce consists of a strategy whereby, once the U.S. was attacked by a Soviet first strike, the U.S. would use its counterforce capability against Soviet reserve nuclear forces in an attempt to reduce our total damage to a point which, even though above the "acceptable" level, would be lower than that we would otherwise sustain. Effective damage-limiting through counterforce strategy is probably difficult due to the technologies involved. Restrained counterforce does not involve a heavy strike for the purpose of reducing significantly the adversary's capability; rather it involves employing nuclear devices to "send them a message," demonstrate resolve, and thereby discourage further escalation.

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[85]McNamara, loc. cit.

3. Implementation of Counterforce

Restrained counterforce is Secretary Schlesinger's changed strategy to provide additional options to the President of the United States in the event of a possible recourse to the use of strategic weapons. Effective deterrence strategy lies in being able to match the opponent at different thresholds of violence and make each escalation more costly for him. The ultimate sanction, that of full-scale nuclear attack on cities, obviously would be considered only in the last resort. However, the United States needs the capability to engage in very small, as well as very large, nuclear exchanges should the situation arise. In addition to such "countervalue" targets as cities, and counterforce targets like missile forces, the restrained counterforce strategy would include targets like military staging areas, hydro-electric and petroleum facilities, dams and bridges. The United States, Secretary Schlesinger believes, requires the ability to destroy these targets with a minimum of collateral damage.

Secretary Schlesinger also believes that the United States needs to maintain a rough symmetry in counterforce capabilities with the Soviet Union. A situation in which, for instance, the Soviet Union had the capability to destroy 80 per cent of the American ICBM force with only 20 per cent of her own force and without the United States possessing a similar capability is believed unacceptable.

This objective, known as "counterforce matching," was based on the assumption that the United States should seek to sustain an "essential equivalence" with the Soviet Union in the overall size and capability of strategic forces. Secretary Schlesinger believes that strategic parity must be apparent; it must be seen to exist by American and Soviet leaders, as well as by third parties.

The principal features of the essential equivalence posture are listed:[86]

1. A capability sufficiently large, diversified, and survivable so that it will provide us at all times with high confidence of riding out even a massive surprise attack and of penetrating enemy defenses,and with the ability to withhold an assured destruction reserve for an extended period of time.
2. Sufficient warning to ensure the survival of our heavy bombers together with the bomb alarm systems and command-control capabilities required by our National Command Authorities to direct the employment of the strategic forces in a controlled, selective and restrained fashion.
3. The forces to execute a wide range of options in response to potential actions

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[86]Schlesinger's News Conference, op. cit.

by an enemy, including a capability for precise attacks on both soft and hard targets, while at the same time maintaining unintended collateral damage.

4. The avoidance of any combination of forces that could be taken as an effort to acquire the ability to execute a first-strike disarming attack against the Soviet Union.
5. An offensive capability of such size and composition that all will perceive it as in overall balance with the strategic forces of any potential opponent.
6. Offensive and defensive capabilities and programs that conform with the provisions of current arms control agreements and at the same time facilitate the conclusion of more permanent treaties to control and, if possible, reduce the main nuclear arsenals.

These factors provide a basic insight into the essential equivalence posture Secretary Schlesinger proposed. Several programs have been recommended to implement this new posture including: improved command and control and rapid retargeting ability; improved inertial guidance for Minuteman; higher yield for MINUTEMAN; increased MIRV multiplicity for MINUTEMAN; increasing the payload on

TRIDENT II SLBMs; and conducting long-term research on terminal maneuvering warhead (MaRV) guidance, which could eventually provide ICBM and SLBM warhead accuracies not significantly different from zero CEP, and on increased MIRV multiplicity.

4. Role of the LRCM in Counterforce

The recommendations do not consider the long-range cruise missile as a potential weapon system that could contributed to deterrence posture. The LRCM is capable of performing many of the functions outlined as principal features of the new program and should be considered in the list of recommended weapon system changes to implement that posture. The sea-launched cruise missile has a high degree of survivability, if the U.S. is attacked by a massive surprise attack, and has a high probability of penetrating enemy defenses and inflicting unacceptable damage on the Soviet Union. Cruise missiles are not detectable by the ABM system and are marginally detectable by coastal defense early warning radars. This makes the LRCM a unique weapon system because the bomber, ICBMs and SLBMs are all susceptible to penetration defenses. The submarine is basically invulnerable from attack, assuming no major improvements in Soviet ASW capability, enabling the weapons platform to withhold an assured destruction reserve for an extended period of time and allowing the negotiation process to function. A LRCM force would enable

the President of the United States to execute a wide range of options in response to potential actions by an enemy, including a capability for precise attacks on both soft and hard targets and at the same time minimizing unintended collateral damage. The LRCM could not be perceived as an effort to acquire the ability to execute a first-strike disarming capability against the Soviet Union, because the warhead yield is small and the flight time to target is long as compared to the ICBM and SLBM throw weights and flight times and would probably not be targeted against ICBM silos. Instead, it would probably be targeted against other counterforce and countervalue targets. The LRCM would be perceived as an effort to gain an overall balance with Soviet offensive strategic forces. The Soviets have approximately 583 LRCM submarine and airborne launch platforms deployed, capable of carrying about 1270 missiles. Deploying the LRCM would enable the United States to attain approximate counterforce matching.

B. DETERRENCE MODEL

Advances in weapons technology have increased the capabilities of strategic offensive and strategic defensive systems and threatened the stability of the present triad as a deterrent system. The criteria for evaluating the impact of advanced technology or deterrence are highly complex, requiring sophisticated mathematical calculations and the construction of complicated models. To facilitate

analyzing and understanding the impact of this technology on stability, an over-simplified deterrent model will be developed to project the amount of stability ICBMs, SLBMs, bombers, MIRVs, ABMs and the LRCM contribute to the deterrence system. In developing this model it is assumed that national governments act in a rational manner to achieve national goals and strategic objectives. It is also assumed that each nation's primary strategy is to maintain retaliatory forces sufficient to deter attack by other nations.

The policy of maintaining such retaliatory forces has been called an "assured destruction" policy. The retaliatory capability after attack should be sufficient to assure the destruction of the aggressor's nation as a viable society. The ability to absorb an all-out attack and still maintain sufficient retaliatory forces is the principal means of deterrence. Hypothetical situations have been studied in which opposing nations feel secure from attack because each believes that no feasible attack would reduce its retaliatory capability to a level potential attackers could accept. This simplified model will be used to analyze such mutual deterrence relationships. First the force required to assure a retaliatory capability must be determined. Next an examination will be made of the effects of introducing the dynamics of force growth for two nations, each attempting to achieve a deterring posture. A comparison

will then be made of the contributing value of land-based missile forces, airborne missile forces and submarine forces to the stability of the deterrence model.

It is assumed that each nation attempts to maintain retaliatory forces it believes sufficient to deter attack by any or all other nations. Since its force could be reduced by an attack, each party must acquire more weapons that it would otherwise deem necessary to deter attack. This attempt to achieve mutual deterrence could result in each party being able to destroy the other by a strike against urban centers but none being confident that he can deter the others from a strike directed against his retaliatory forces. It is easy to imagine this situation could lead to an "arms race." Even if stability of armaments is held to be achieveable, it could be viewed as a fragile situation dependent on some sort of parity being maintained between the parties involved and the avoidance of a "missile gap" or a "throw weight gap." As a simple instance, consider a nation fearing an attack by another. Suppose each believes that two surviving weapons are sufficient to deter attack. If, on the average, it takes two weapons to neutralize one, it is easy to see where this theory could end up in an arms race. If each nation buys two weapons, each is faced with the possibility of attack by four, which could eliminate its force. It must then buy two more and so on. This intuitive description of an arms race can be

quite misleading. The fallacy lies in the phrase "on the average" it takes two weapons to neutralize one, which does not account for the diminishing threat posed by additional weaponry.

A simplified deterrence model will be developed that illustrates the "diminishing returns" phenomenon. It is an idealization of the situation presented by single and multiple warhead missiles located in sites dispersed and hardened against nuclear attack and on airborne and sea-based platforms. Using this model it can be illustrated that unlimited arms races need not necessarily occur in the mutual attempt to achieve deterrent forces providing both sides have similar numbers of warheads, delivery systems and throw weight or "essential equivalents."

In developing this idealized model, the number of missiles the United States and the Soviet Union had deployed at the time of the Interim Agreement of May 27, 1972, will be utilized. It is believed the Soviets had about 1618 missiles and the U.S. 1054 missiles. As previously discussed, deterrence depends on a nation's ability to deliver unbearable or unacceptable damage to another. Secretary McNamara indicated that in the case of the Soviet Union, destruction of one-fourth to one-third of her population and one-half of her industrial capacity would serve as an effective deterrent. Such a level of destruction would probably represent adequate punishment

to any twentieth century industrial nation. Legault and Lindsey[87] have developed an algebraic expression for a deterrence model which will be utilized to develop this model and analyze the impact of different weapon systems on this model.

Our mutual assured destruction framework has led us to the position where our strategic weapons policy is the result of a mathematical model of force design. Within this model a series of points or areas exist which yield the numbers and types of missiles the United States and the Soviet Union should maintain for stable deterrence. A deterrence model can be graphically represented (see Figure 1). The United States and the Soviet Union represent opponents in a two-party duel which will be represented by X and Y, respectively. N_x is the number of missiles X possesses and N_y is the number of missiles Y possesses. U_y is expressed as a threshold, representing the damage Y's missiles could inflict on X's cities, which is considered intolerable for X, and beyond which X would be deterred from any further offensive action for fear of provoking such injury. Similarly, U_x is a threshold representing the damage X's missiles could inflict on Y's cities, which is considered intolerable for Y.

The deterrence model proposes that the two thresholds U_x and U_y need not necessarily be the same number of

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[87]Legault and Lindsey, op. cit., p. 170-188.

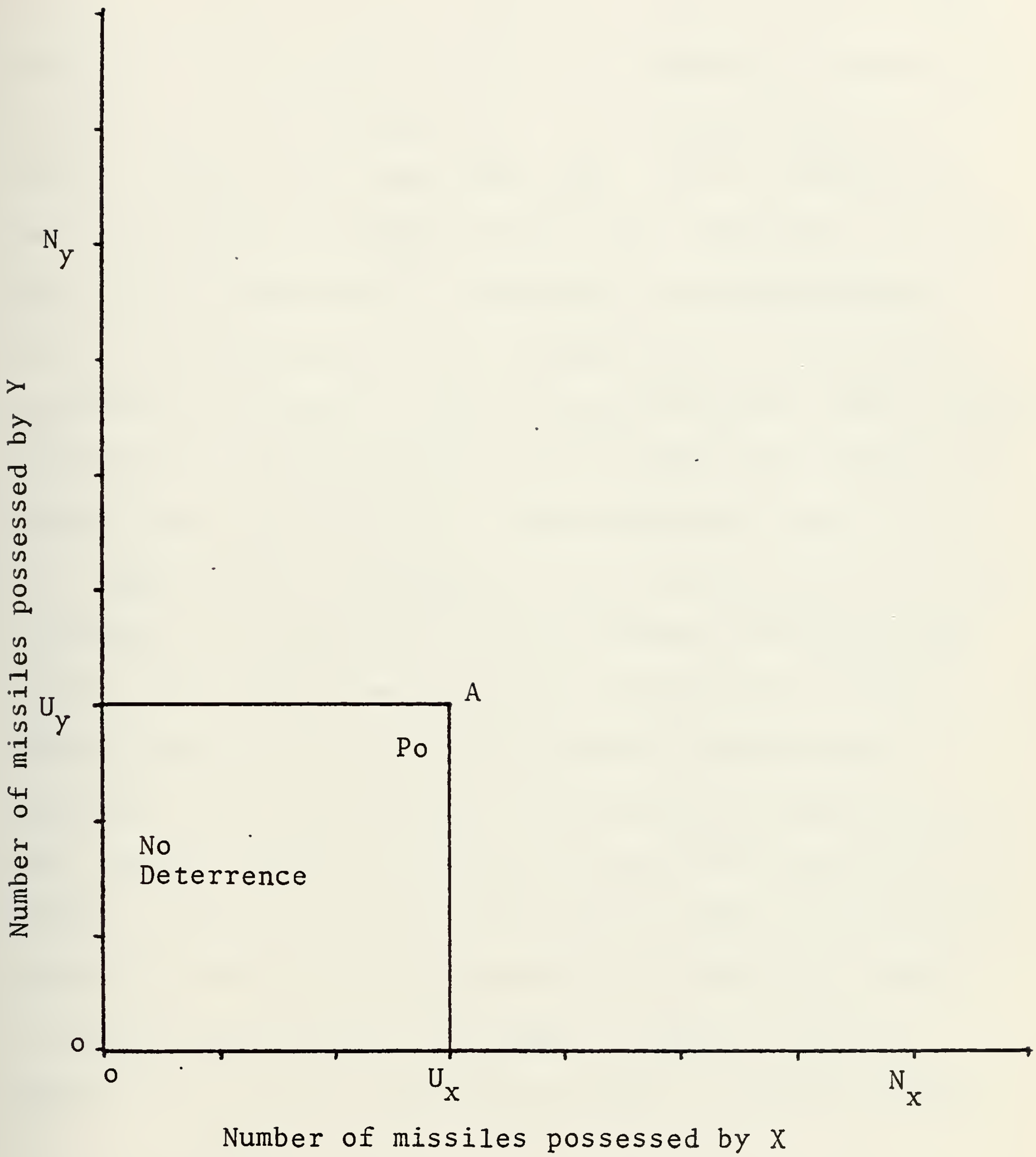

Figure 1. Threshold of deterrence

missiles. Typical population densities for some U.S. major cities on a 40-square-mile basis approach 15,000 people per square mile as compared to major Soviet cities which are smaller and have population densities approaching 20,000 persons per square mile. On balance though, the Soviet population is more rural than the U.S. population. Two hundred and one Soviet cities have populations of more than 100,000 inhabitants, accounting for approximately 30% of the total population, whereas 65% of the total U.S. population is located in 216 cities having more than 100,000 inhabitants. Only 10 major Soviet cities have populations greater than one million.[88] Forty-three per cent of the U.S. population is targetable by the SS-N-3 cruise missile (assuming a 550 NM missile range launched 200 NM from the coast). This percentage includes 138 major U.S. cities having populations greater than 100,000 inhabitants.[89] Generally for a given weapon yield, greater density cities will result in higher casualties than lower density cities. However, since the Soviet population is more rural and the cities are smaller, larger numbers of weapons are needed to inflict equal levels of damage. Tables 12 and 13, Appendix A, list the approximate number of one MT weapons

[88]See Appendices B and C.

[89]See Appendix D.

needed to inflict a 25% casualty rate on the U.S. and U.S.S.R. as 250 and 200, respectively. Potential targeting for casualties greater than 25% would require increasingly larger numbers of weapons eventually approaching an exponential growth rate. Appendix B lists the major cities and Table XIII displays the number of cities targeted to efficiently attain a potential 25% casualty rate. As evidenced by Table XIII all major cities were potentially targeted to attain a minimum unacceptable damage level.

One nation may be prepared to face greater sacrifices than the other, influencing the "unacceptable damage" threshold the other may perceive as unbearable. Hence X and Y may not make the same estimates of U_x and U_y. A key point which must be emphasized in building this model is that the number of missiles needed is X's estimate of what Y perceives is unacceptable damage to X and U_y is the number of missiles required to inflict that perceived unbearable damage. Similarly, U_x is the number of missiles required to inflict what X perceives as unacceptable damage to Y and U_x is the number of missiles required to inflict that damage. U_x and U_y's thresholds may be interpreted differently by different officials in both the U.S.S.R. and U.S.; however, in constructing this model, a 25% casualty rate will be considered as acceptable damage for both the U.S. and U.S.S.R. The number of weapons required to inflict 60 million casualties can be determined

utilizing scaling techniques on empirical data collected from the Japan incident. Appendix E contains a comprehensive analysis of how casualties are translated into numbers and yields of warheads. From this analysis it was determined that to inflict unacceptable damage (60 million casualties) on the Soviet Union, the U.S. needs approximately 250 one-MT warheads and the U.S.S.R. needs approximately 200 one-MT warheads to inflict similar damage on the U.S. (50 million casualties).

Figure 1 shows a rectangle OU_xAU_y. Any point such as Po which is inside this rectangle represents a situation in which there is no deterrence in either direction. In constructing this model, partial deterrence is neglected and the assumption is made that U_x and U_y represent deterrence for X and Y. Hence U_x and U_y actually represent the number of missiles (warheads) that must survive a first strike (commonly known as the second-strike force) which are then launched by the attacked country against the attacker's cities (countervalue) and are capable of inflicting unacceptable damage to her population and industrial capacity; hence, the theory of mutual assured destruction. A more detailed development of this model is contained in Appendix F.

When the point $P(N_x, N_y)$ in Figure 1 is outside the box marked "no deterrence," the situation becomes more complex. Suppose that X has N_x missiles greater than U_x.

X can keep U_x of his missiles in reserve, to threaten Y's cities, and use the remaining missiles to launch a counterforce strike against Y's missiles. This model assumes all missiles are ICBMs installed in hardened silos. If the attack is initiated, a certain number of Y's missiles would be destroyed. The key factor which must be considered by X is how many of Y's missile silos can be destroyed in the attack. Considering only the ICBM portion of the Triad, if Y is left with at least U_y missiles, Y can retaliate against X's cities and inflict unacceptable damage. Hence, the deterrence model functions on the principle that unless the potential attacker can destroy enough missiles in a counterforce strike to reduce the number of missiles below the U_x or U_y level, the attacker is deterred. The attacker would not have a first-strike capability and the attacked country would have a second-strike capability. The number of missiles that could be destroyed in a counterforce strike depends on a number of factors discussed in Appendix E.

Suppose that C_x designates the probability that, if one of X's missiles is fired at one of Y's missile silos, the target will be destroyed. Similarly C_y would designate the probability of destroying one of X's missile silos.

The next model (see Figure 2) considers the U.S. and U.S.S.R. strategic missile forces deployed on submarines. Submarines at sea are considered invulnerable; hence, the

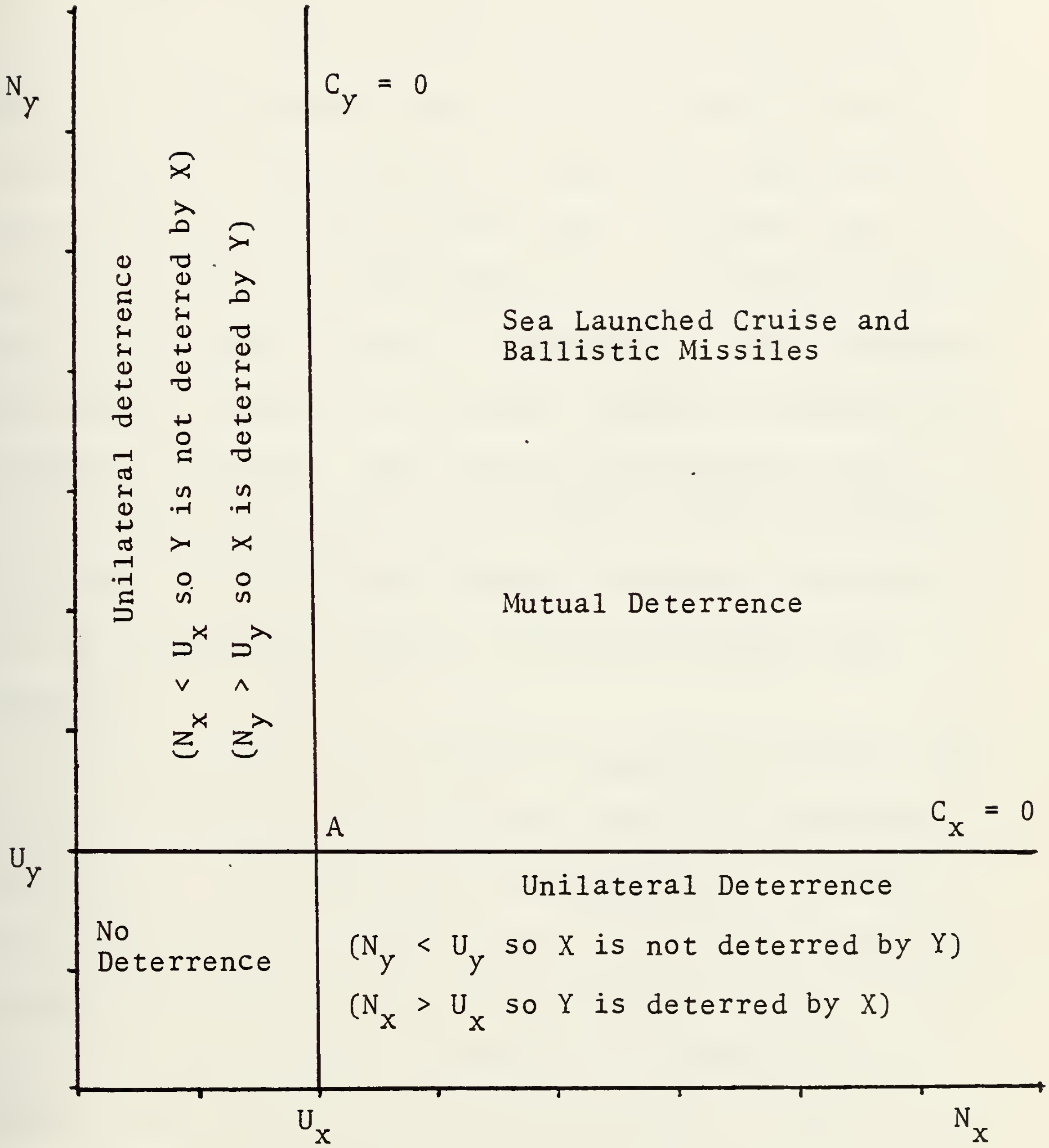

Figure 2. Possible deterrent situation for SLBM's and SLCM's.

coefficients of counterforce effectiveness, C_x and C_y, would be equal to zero. In this model there is no counterforce capability and it approaches an ideal stable deterrent posture. More than half the U.S. strategic missile force and approximately one-third the Soviet strategic missile force is maintained in submarines which greatly increases the stability of the total strategic model. If there is no effective ABM defense for the cities, then all area to the right of point A represents a state of mutual deterrence. Should all strategic weapons be deployed on submarine platforms, there would be no potential for a first-strike capability, thus maximizing the stability of the model. The two zones labeled unilateral deterrence are self-explanatory and are discussed in detail in Appendix F.

The next model (see Figure 3) considers the U.S. and U.S.S.R. strategic missile forces deployed in hardened ICBM silos. The coefficients of counterforce effectiveness, C_x and C_y, are greater than zero but less than one. Assume that the thresholds of deterrence are $U_x = 250$ and $U_y = 200$ as discussed in Appendix E. Suppose X is contemplating a counterforce strike against Y's silos. If X is not capable of destroying enough of Y's missile silos to reduce her force to less than U_y, X will not be able to strike. Missiles are not one-hundred per cent reliable and appropriate computations can be made to more accurately

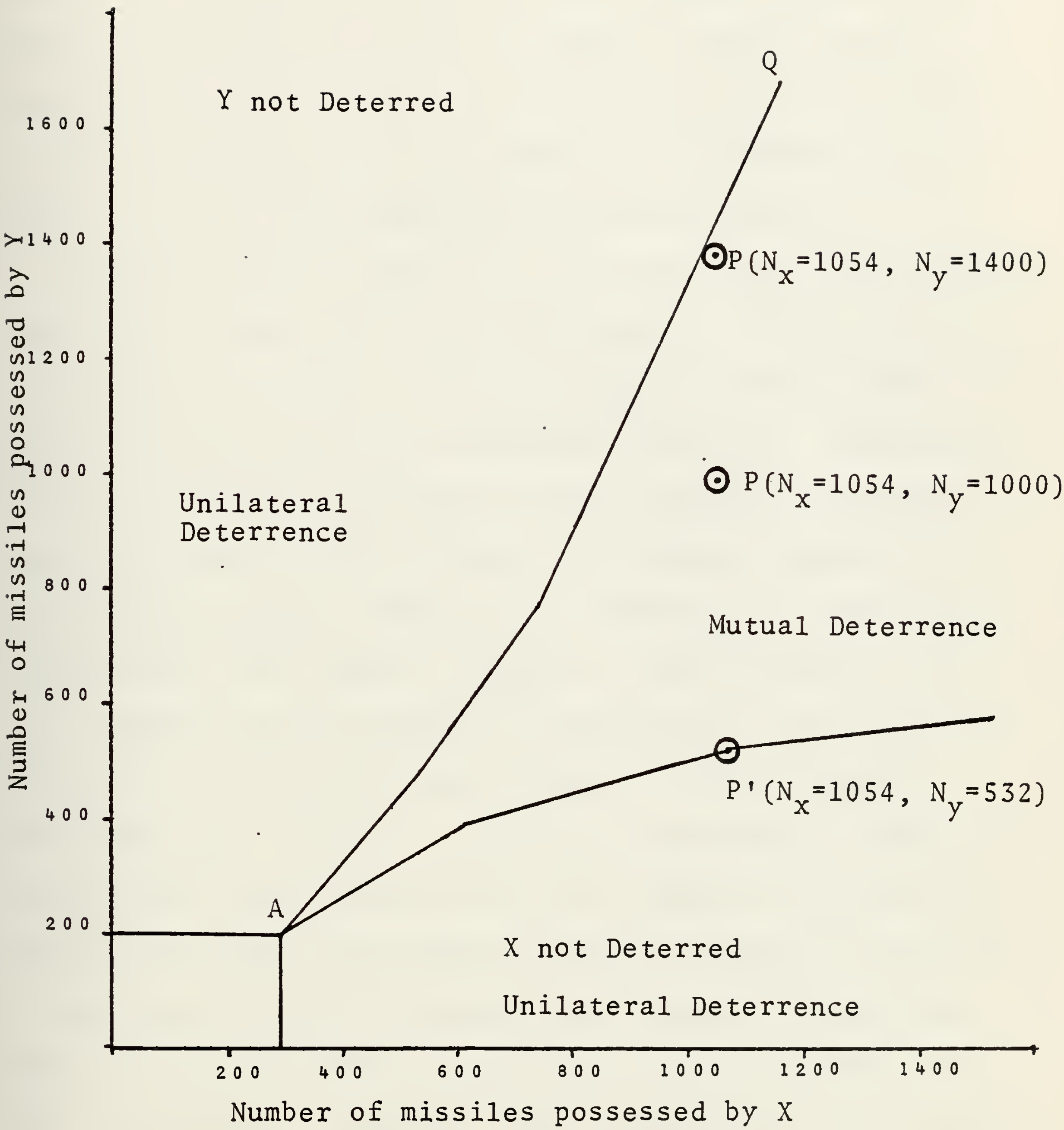

Figure 3. Deterrence of X by Y.

determine the number of missiles required to destroy a target. $U_x = 250$ and $U_y = 200$ thresholds would be the number of missiles which reach their targets and not the number available for potential launch. Assume that the counterforce effectiveness coefficient C_x is 0.5, so that a missile belonging to X and aimed at Y's missile silos has a fifty per cent probability of destroying it.

Consider the case where C_x is 0.5 and X has 1054 missiles and Y has 532 missiles $P(N_x = 1054$ and $N_y = 532)$; see Figure 3. X can afford to aim two of his missiles at each of 268 silos, and one each at the remaining 264 silos. Employing probability laws, the number of silos expected to survive the attack would be 200, which is the number required to inflict unacceptable damage on X, assuming no losses due to malfunctions from launch to impact. Hence, when $N_y \geq 532$, X is deterred from attacking Y, but when $N_y < 532$, X is not deterred. P marks the point between a state of mutual deterrence and a state of unilateral deterrence. Similar calculations can be made varying the numbers of X and Y's missiles obtaining the geometric locus obtained in Figure 3.

In constructing the models three states of deterrence were identified: mutual deterrence, unilateral deterrence or no deterrence. Stability could be defined as the absence of a rational motive to launch an attack. When a rational motive exists on either side to launch a first strike, there is instability. It is possible to have a state of stable

deterrence or of unstable deterrence. See Figure 4. Stability is not necessarily associated with near equality of forces on both sides either. Assume X possesses a very large force but Y does not have enough missiles to inflict punishment on X by an unopposed countervalue first strike; a stable unilateral deterrence state would exist. Should Y begin accumulating missiles, alarming X over the intended use of the missiles, X could disarm Y before reaching the threshold of deterrence U_y, and the state of unilateral deterrence would have become unstable. The zone labeled AQ and AP is an area of stable mutual deterrence. All points falling in this zone will result in stable mutual deterrence, since neither side has the ability to launch a counterforce first-strike and destroy enough missiles to keep the other side from retaliating.

The ALCM was not considered in the deterrent model.

C. STRATEGIC FACTORS

Some general conclusions can be drawn when considering the various combinations of strategic forces and their impact on the deterrence model. Increasing accuracies of land-based ICBMs decrease the stable mutual deterrence zone and decrease the overall stability of the model. MIRVing ICBMs produces a double unstable zone and reduces the stable mutual deterrence zone, further decreasing the stability of the model. SLBMs are currently invulnerable

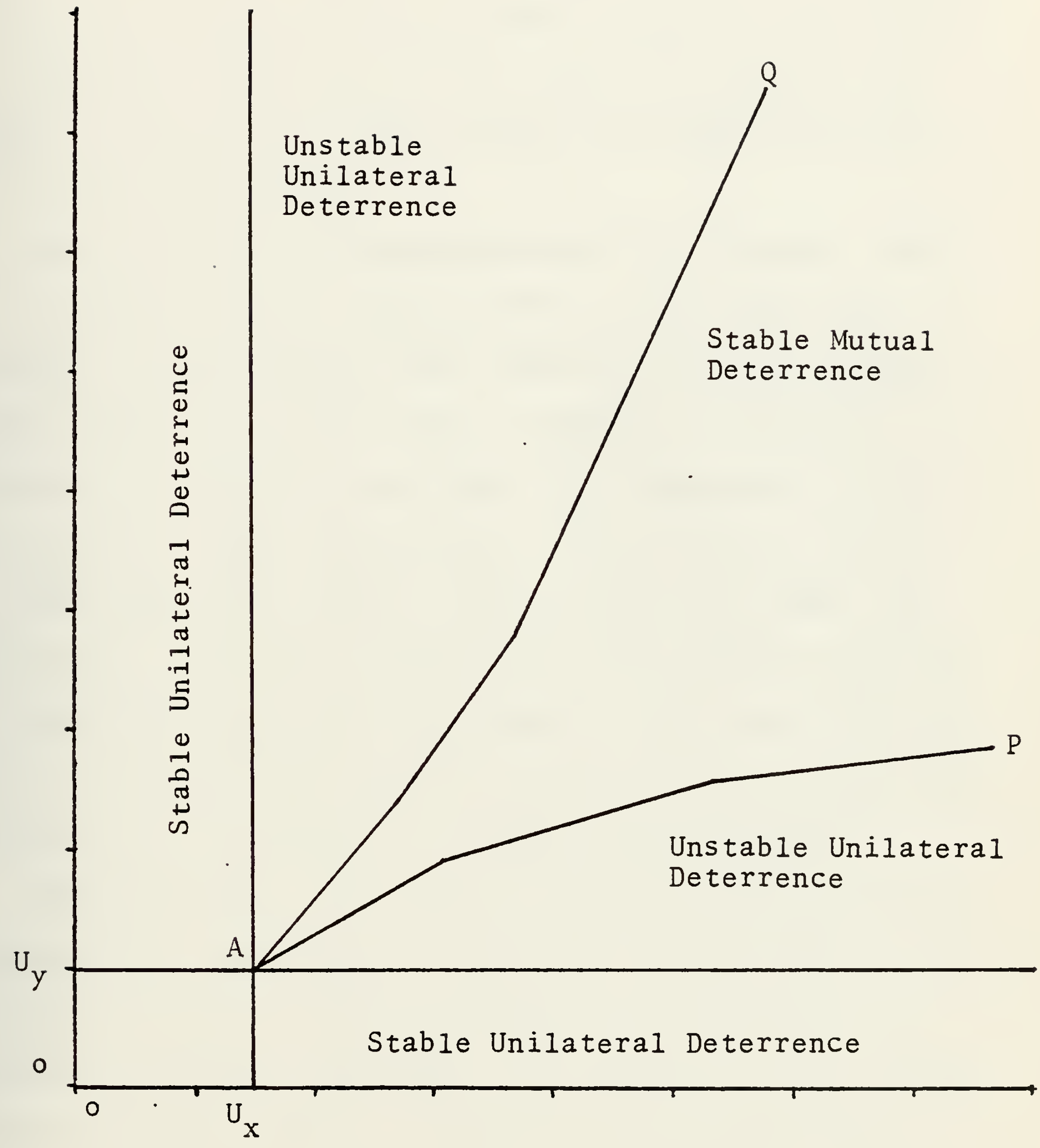

Figure 4. Stable and unstable deterrence.

to a pre-emptive first-strike attack, making the submarine launched missile platform the stabilizing factor in the deterrence model. If all strategic missiles were deployed on submarines, the unstable unilateral deterrence zone would be replaced by stable mutual deterrence resulting in a very stable model.

Bombers have not been addressed in this model. They are vulnerable to pre-emptive first strike, but with adequate threat warning their bomber base survivability would probably be fairly good. Bombers are probably primarily considered a non-ICBM silo counterforce and countervalue weapon, and may not factor into the first-strike counterforce model to the extent that ICBMs and SLBMs do. Admittedly, bombers could be targeted against hardened ICBM silos, but the bomber's force was initially built to support the massive retaliation doctrine and that mission was not designed to strike hardened silos.

EMP phenomenon and fratricide effects could very well increase the importance of the bomber and the LRCM in a nuclear exchange. Radiation effects on the complex and delicate electronic equipment of a missile and its launching facilities, even in a reinforced and shilded silo, are not completely understood by the scientific community. Real-world nuclear radiation effects may prove the bomber to be the most reliable and potent force of the land-based Triad systems. Bombers carry the bulk of the U.S.

megatonnage making them a very important contributing force to deterrence. The force can be effectively employed in foreign policy efforts to demonstrate resolve because it still maintains the man-machine interface and can be called back once launched. Inflight retargeting is another important function the bomber can accomplish by maintaining a "man in the loop" policy. This might also apply to the air-launched cruise missile.

The bomber force carries four and one-half times the megatonnage the Soviet bomber force carries, making the U.S. "total" potential timely deliverable weapons yield less efficient than the Soviets, who have the majority of their potential throw weight on ballistic missiles. Soviet ballistic missile CEP improvements could gain them a significant hard target kill potential, resulting in an unstable counterforce asymmetry. The Soviets would then acquire a strategic coercive capability enabling them to greatly influence foreign policy objectives. Secretary Schlesinger's projected Soviet CEP estimate of 500 to 700 meters by the mid-1980's suggests that such a strategic imbalance will exist in the near future.

Assessing the bomber and missile forces' contribution to the future deterrence model is difficult to analyze without considering the type of war which will be fought. A massive pre-emptive first strike followed by an aggressive second strike, instead of attempting to resolve the conflict

through negotiations, combined with accelerated nuclear war fighting doctrine, would favor the missile as a delivery vehicle. Scenarios emphasizing the negotiation process, but stopping short of nuclear war, may favor the bomber because of its ability to be called back.

The area between massive pre-emptive strike and successful negotiations is a very gray area which could be viewed from a potential nuclear war fighting point of view as being in the Soviets' favor because their potential throw weight advantage could be translated into perceived strategic superiority and be used in negotiations as a coercive means of gaining their objectives.

Restrained counterforce strategy probably best describes the gray area discussed. Restrained counterforce does not involve a heavy strike for the purpose of reducing significantly the adversary's capability; rather it involves employing nuclear devices to demonstrate resolve or "send them a message" and thereby discourage further escalation. Restrained counterforce is Secretary Schlesinger's strategy to provide additional options to the President of the United States in the event of a possible recourse to the use of strategic weapons. Effective deterrence strategy requires matching the opponent at different thresholds of violence and making each escalation more costly for him. The ultimate sanction, that of full-scale nuclear attack on cities, obviously would be considered only in the last

resort. The bomber force may not be as efficient in some cases, in executing a restrained counterforce scenario as a highly accurate LRCM surgical strike, but it does have some advantages. A general assessment of the bomber and its impact on the deterrence model must include its inherent flexibility as a launch platform which contributes to stability. The amount of stability it contributes is a function of the type of war being fought and the targeting philosophy of a country. The model was constructed using the ballistic missile as the counterforce target to aid in understanding deterrence stability. Although bombers could be factored into the model, such effort was not deemed worthwhile for this study. Without modeling, it could be assessed that the bombers contribute to the stability of the deterrence model and the degree they contribute is a function of the war fighting scenario being considered.

Focusing now on the long-range cruise missile and its potential contribution to the deterrence model discussed, some general observations can be made concerning its contribution to deterrence. The sea-launch cruise missile would be invulnerable to attack contributing stability to the deterrence model. Like the SLBM, the coefficient of counterforce for the SLCM would be zero. As a result, the stable unilateral deterrence zone would be increased, discouraging the Soviet Union from launching a pre-emptive first strike. The LRCM would contribute to the restrained counterforce

strategy because of its surgical strike capability, providing the President additional strategic options in the event of a possible recourse to the use of strategic nuclear weapons. Delivering weapons with precision, even at very long ranges, would make it possible to substitute small weapons for large ones and reduce potential casualties. This capability would greatly increase the effectiveness and discrimination with which force can be applied in demonstrating resolve. These developments would contribute to the goal of being able to respond to different functional levels of conflict managed in scope according to the goals of the foreign policy objectives involved. The prospect of being able to implement more effective action, with less collateral damage, would enhance our deterrence posture and greatly increase the stability of the model when engaged in different levels of war fighting strategy.

High probabilities of penetrating enemy defenses and striking targets with surgical accuracy contribute to deterrence stability because the adversary would not be allowed prior warning of a launch until the specifically identified target was destroyed. Having the capability to engage in conflict with this degree of control would greatly decrease the probability of conflicts escalating to total nuclear exchange. The adversary's knowledge of a reserve force having a high degree of survivability which was capable of inflicting unacceptable damage would

persuade that actor to consider negotiations instead of further confrontation. Threatening to destroy a specific target and then surgically removing it would gain a great psychological advantage and bring stability to a potential unstable situation.

Sea-launched cruise missiles could contribute stability to the potential ICBM counterforce asymmetry. The LRCM has reached an advanced development stage enabling rapid deployment to counter that threat, as compared to other weapons system modifications which are not scheduled to become operational until the mid-1980's. The LRCM could be operational by the early 1980's[90] and provide the U.S. a margin of deterrence stability, should the Soviets' new family of ICBMs become operational before the planned weapons modifications are deployed. The Soviets could use their throw weight advantage as a coercive attempt to influence foreign policy, but perceiving the surgical strike capability of the LRCM, they would be dissuaded from emphasizing that advantage and deterrence stability would be maintained.

Reprogramming LRCMs to targets which were assigned to ballistic missiles, but never destroyed due to malfunctions in the various flight stages, ABM interceptions, fratricide-induced inaccuracies or other problems, could be an important role for the missile. The platform would be positioned in

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[90]U.S. Senate Hearings, op. cit., p. 5139.

the forward area near the action zone enabling near real-time reprogramming and employing the shoot-look-shoot technique.

The air-launched cruise missile (ALCM) has similar targeting capabilities. The survivability of the platform is probably not as invulnerable as the submarine at present, but randomly based and forward deployed aircraft could provide an adequate degree of survival, contributing to deterrence stability. Air-launched cruise missiles deployed on bombers and launched in conjunction with bomber defense penetration would probably provide a higher probability of bomber survival due to defense saturation. ALCM flight altitudes would probably decrease rapidly after aircraft separation confusing the air defense system. Once launched, the ALCM would function in the same manner as the sea-launched cruise missile.

The Soviet Union has approximately 113 submarine and aircraft strategic cruise missile launch platforms deployed capable of carrying about 420 missiles. These platforms increase the Soviets' deterrence stability because they are not as vulnerable to attack as silos. Recent open-source literature indicating the Soviets' development of the SS-NX-12 as a possible replacement for the SS-N-3 and modification of the AS-4 for installation on the BACKFIRE indicates the Soviets' demonstrated satisfaction with the cruise missile as a possible strategic or tactical weapons

system. Deployment of the U.S. LRCM in at least the same numbers would further increase the stability of the deterrence model.

V. SALT IMPLICATIONS

A. BACKGROUND

The Vladivostok agreement signed on November 24, 1974, is a relatively straightforward document which provides an overall ceiling of 2,400 strategic delivery vehicles for each party with a sub-limitation of 1,320 missiles which may be equipped with MIRVs.

The Vladivostok aide memoire was intended to set the framework for a new interim agreement between the two powers on the limitation of strategic weapons. The aide memoire was intended as a simple document which would serve as an interim agreement while the arms control delegations of the two countries drafted an agreed text for a second Strategic Arms Limitation Treaty (SALT II), which President Ford and Secretary Brezhnev were to sign at a Washington, D.C., summit meeting in June, 1975.

The aide memoire has remained a classified document available to a limited number of people, but published open-source literature indicates that knowledgeable U.S. Government officials and Soviet officials interpret the document with different understandings.

The two delegations commenced their formal meetings in Geneva on January 30, 1975, and after three unproductive months they recessed the talks in early May when it became clear that the middle-echelon arms control officials could

not come to an agreement on critically important differences and that a top-level negotiating effort would be necessary to resolve the differences. An official announcement was then made that the summit meeting in Washington would have to be delayed until the fall at the earliest.

What became clear in the three months of discussions between U.S. and Soviet arms control delegations in Geneva is that the aide memoire raised as many unexpected new questions as it attempted to answer. MIRV verification and counting the BACKFIRE bomber as a strategic launcher are two problems. The third problem which developed is the status of the cruise missile. The Vladivostok understanding provides that air-launched missiles with a range in excess of 600 km will be counted against the overall ceiling of 2,400 delivery vehicles. The air-launched cruise missile (ALCM) now in advanced development by the Air Force would have a range capability in excess of 600 km (372 miles). A single B-1 bomber will be able to carry 24 of these weapons. Under a literal interpretation of the aide memoire, a single B-1 with this force loading would count as one per cent of the overall allowance of 2,400 delivery vehicles. This limitation is obviously unacceptable to the U.S. Government. The U.S. and Soviet Union have maintained operational bomber-launched cruise missiles, the Soviet KANGAROO and the U.S. HOUND DOG, having ranges in excess of 600 km for years which were not previously considered in SALT negotiations.

B. RECENT PROPOSALS

The status of the sea-launched cruise missile (SLCM) was evidently not considered in any way by the Vladivostok accord, and available literature indicates there was little discussion of the SLCM in the Geneva negotiating sessions.

The Soviet Union's proposals in the January, 1976, round of SALT talks in Moscow tie reductions of strategic delivery vehicle limits below the 2,400 set in Vladivostok to restrictions for the U.S. sea-launched cruise missile. The U.S. expects to resume negotiations in the spring of 1976 with counter-proposals modifying the Soviet offer. Details of the Soviet proposal include: (1) A reduction of total strategic delivery vehicles to a level of about 2,200. This would require the Soviets to phase out some systems now operational, while the U.S. is currently below the level proposed. Both sides, however, would be limited to deployment of new strategic systems without reductions in other areas. This new limit is linked to the BACKFIRE and cruise missile deployment issues. (2) Permitting deployment of the ALCM without limiting the range to 600 Km. Air-launched weapons would not count within the 2,400 limit for strategic delivery vehicles or the reduced ceiling proposed by the Soviets, but bombers or tanker aircraft armed with ALCMs would count within the 1,320 MIRV ceiling which would remain unchanged from Vladivostok. (3) Limitations on the SLCM to the 600 Km the USSR has already

proposed. The Soviet position is that SLCMs with a range in excess of 600 km would be counted in the strategic delivery ceiling.[91]

The SLCM proposal is not a realistic proposal because "the Soviets already have operational more than 2000 SS-N-3 cruise missiles...in all types of platforms...and the weapon is considered to have a nuclear warhead,...the U.S.S.R. can cover half the U.S. from the 100-fathom line of the coast with the SHADDOCK cruise missile's range and warhead."[92]

C. VERIFICATION

The greatest disadvantage of the long-range cruise missile, and especially the submarine-launched version, is its impact on arms limitation efforts. The obvious prerequisite for any international agreement limiting one or more weapon system is that the agreement can be verified. It has become customary practice to require that the verification can be carried out without on-site inspection. The theorem then that governs arms limitation is that an agreement on limiting a weapon is possible only if compliance to it can be verified by non-intrusive means, that is, by national technical means.

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[91] Robinson, C. A., "Soviets Make New SALT Bid," Aviation Week and Space Technology, v. 104, p. 12, 2 February 1976.

[92] Ibid., p. 15.

The SLCM now being developed includes two versions, one strategic and one tactical, which are externally identical. In addition, since both weapons will be encapsulated in a canister for firing from a torpedo tube, it will be physically impossible to distinguish between the two versions without literally dismantling the weapon. Since this constitutes highly intrusive inspection, it will be unacceptable to both the U.S. and Soviet Union.

The desirable method for controlling the proliferation of strategic cruise missiles would probably be placing a limit on the number of platforms that carry the missile. The Soviet Union presently has 67 submarines deployed with cruise missiles. Not all platforms are modern nuclear submarines so possibly allowing each country 40 launch platforms may be a reasonable solution to the missile control and proliferation problem.

VI. CONCLUSIONS

A. GENERAL

The long-range cruise missile will add a measure of stability to the strategic deterrent balance and contribute to the restrained counterforce doctrine. The sea-launch cruise missile platform would be invulnerable to a counterforce first-strike attack providing the United States with a non-time sensitive reserve weapon capable of inflicting unacceptable damage on the adversary, hence increasing the stability of deterrence. The long-range cruise missile would contribute to the restrained counterforce strategy objective because its low probability of intercept and surgical strike capability would provide the President of the United States additional strategic options in the conduct of foreign policy. This capability would greatly increase the effectiveness and discrimination with which force can be brought to bear in demonstrating resolve.

Geographic asymmetries between the United States and Soviet Union influence the sophistication and range a cruise missile must possess to attain similar targeting results. The U.S. coasts are readily accessible by medium-range missiles launched from submarines whereas the Soviet coasts are inland, for the most part, requiring long-range missiles having more complex guidance systems.

Upgrading the SS-N-3 with current state-of-the-art turbofan technology could enable the Soviets to attain ranges of approximately 1500 miles and allow them the potential to strike most of the countervalue targets in the United States.

SS-N-3 guidance improvements would probably be required should the Soviets upgrade the power plant with a turbofan engine. Employing "off the shelf" ICBM inertial guidance technology could yield accuracies of a few hundred feet at ranges of 1500 miles.

Employing a Tercom type system in the SS-N-3 missile would probably not be cost-effective for the Soviets. Effective countervalue strikes can be obtained without employing this level of technology.

More than fifty per cent of the total U.S. population lives within potential targeting range of the Soviets' SS-N-3. Approximately 50% of the population, targetable by the SS-N-3, lives in cities having more than 100,000 inhabitants. The Soviets could potentially inflict unacceptable damage on the United States using their cruise missile weapons systems in a strategic role. Improving the range and accuracy of their cruise missiles would allow the Soviets to potentially strike a great majority of U.S. countervalue and a significant number of counterforce targets.

The most salient targeting asymmetry is the distance from reasonable secure weapon launch positions to Soviet

counterforce and countervalue targets. The majority of the U.S. population is concentrated near the coasts whereas the majority of the Soviet population is located greater than 1000 NM from various European waters. This factor makes the U.S. cruise missile potential targeting problem much more difficult than the Soviets'.

The LRCM poses a challenge to present early warning systems and air defense forces in both the U.S. and the U.S.S.R. Radar cross-section reduction efforts have decreased the U.S. SLCM radar return to a size where current air defense radars will probably not be capable of adequately detecting and tracking. New radars or other types of sensors capable of operating against a low-altitude small radar cross-section target will probably have to be developed.

The major portion of the U.S. strategic megatonnage is deployed in the strategic bomber, compared to the Soviets who have their major portion deployed in strategic missiles. This throw weight advantage coupled with an increased ballistic missile accuracy will pose a substantial first-strike threat to U.S. land-based ICBM's by the mid-1980's.

Increased re-entry vehicle accuracies will greatly increase Soviet weapons lethality. A plausible mid-1980's ballistic missile deployment could allow the Soviets to gain a three-to-one advantage in both counterforce and countervalue potential. Deploying the SLCM would decrease

the CMP asymmetry "gap" and decrease the potential strategic instability.

The Soviets could use their potential throw weight and lethality advantage as a coercive attempt to influence foreign policy decisions. However, their knowledge of the U.S. LRCM surgical strike capability would dissuade them from exploiting that political and military advantage.

The Soviets' proposal to limit the SLCM range to 600 Km would allow the Soviets to maintain a weapon system capable of potentially inflicting unacceptable damage on the United States. Denying the U.S. the opportunity to deploy a similar system would greatly decrease deterrence stability and create an equivalence "gap."

New technologies would not be employed allowing the adversary an opportunity to further expand his missile capabilities and threaten the present stable strategic balance.

APPENDIX A

SOVIET SURFACE-SURFACE CRUISE MISSILES[93]

Missile	IOC	Max Speed	Range (NM)	L'th (FT)	Launch Platform	No. Tubes/ Launchers	Notes[94]
SS-N-1	1958	0.9M	130	22.5	1 "KRUPNY" Destroyer	2	Autopilot Guidance
SS-N-2	1960	0.6	23	15	15 "KOMAR" FAC	2	Autopilot Guidance
					65 "OSA-I" FAC	4	
SS-N-3	1961-62	0.9-1.5	250	42	4 "KYNDA" Cruisers	8	Autopilot Command Guidance Nuclear Warhead
					4 "KRESTA I" Cruisers	4	" "
					16 "JULIET" Submarines	4	" "
			550[95]		27 "ECHO II" Submarines	8	" "
					7 "WHISKEY LONG BIN" Submarines	4	" "
					5 "WHISKEY TWIN CYLINDER" Submarines	2	" "

93 Moore, J. E. Capt., RN, FRGS, Jane's Fighting Ships, 1975-76, p. 550, Paulton House, 1975.

94 "Soviets Press Anti-Ship Missile Effort," Aviation Week and Space Technology, v. 96, p. 61, 21 February 1972.

95 Hotz, R., "Pitfalls of SALT II," Aviation Week and Space Technology, v. 103, p. 9, 15 December 1975.

SOVIET SURFACE-SURFACE CRUISE MISSILES

Missile	IOC	Speed	(NM)	(FT)	Launch Platform	No. Tubes/ Launchers	Notes
SS-N-7	1969-70	1.5	30	22	12 "CHARLIE' Submarines	8	Autopilot Guidance Submerged Launch
SS-N-9	1968-69	1.0+	150	30 (est)	12 "NANUCHKA" Missile Corvettes	6	Autopilot Guidance
SS-N-10	1968	1.2	29	25 (est)	3 "KARA" Cruisers	8	Autopilot Guidance
					8 "KRESTA II' Cruisers	8	" "
					9 "KRIVAK" Destroyers	4	" "
SS-N-11		.9	29	21	55 "OSA II" FAC	4	Autopilot Guidance
					4 Modified "KILDIN" Destroyers	4	" "

SOVIET AIR-SURFACE CRUISE MISSILES[96]

Missile	IOC	Speed	(NM)	Launch Platform	Launchers	Notes[97]
AS-1		0.9	55	50 "BADGER B" Bomber	2	Beam rider with semi-active terminal homing.
AS-2		1.0+	115	150 "BADGER C" Bomber	1	Autopilot with a command override.
AS-3		1.5+	400	20 "BEAR B" and "C" Bomber	2	Active Guidance.
AS-4		2.0+	185	"BLINDER B" Bomber	1	Inertial Guidance.
AS-4 Mod[98]			425	? "BACKFIRE B"	2	Nuclear Warhead.
AS-5		0.9	120	150 "BADGER G"	2	Autopilot guidance with command over-ride.
AS-6	1970	2.0	300?	50 "BADGER MODIFIED" Bombers Possible also to be used on "BACKFIRE"	2	Inertial guidance with a command override capability.

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[96]Moore, op. cit.

[97]"Soviets Press Anti-Ship Missile Effort," op. cit., p. 61, 21 February 1972.

[98]Robinson, op. cit.

APPENDIX B

SOVIET CITIES OVER 100,000 INHABITANTS: CUMULATIVE POPULATION, CITY DENSITIES, AND TARGETING DATA[99]

Rank	City	Pop. (000)	Cuml't Pop. Million	City Area Sq. Mi.	Thousands Per Sq. Mi. Density	% of Tot Pop.	Warheads Required 50KT	Warheads Required 1MT	Cumulative Warheads 50KT	Cumulative Warheads 1MT
1	Moscow	7172	7.17	346	20.7	2.85	43	6	43	6
2	Leningrad	4002	11.17	250	16.0	4.45	31	4	74	10
3	Kiev	1963	12.86	297	5.7	5.13	37	6	111	16
4	Tashkent	1424	14.28	87	16.4	5.70	11	2	122	18
5	Baku	1292	15.57	77	16.7	6.21	10	2	132	20
6	Kharkov	1248	16.82	105	11.9	6.70	13	2	145	22
7	Gorkiy	1189	18.01	128	9.3	7.20	16	2	161	24
8	Novosibirsk	1180	19.19	182	6.5	7.65	23	3	184	27
9	Kuybyshev	1069	20.26	134	7.9	8.07	17	2	201	29
10	Sverdlovsk	1048	21.31	150	6.9	8.50	19	3	220	32
11	Tbilisi	907	22.21	103	8.8	8.85	13	2	223	34

[99]Kemp, G., "Nuclear Forces for Medium Powers, Parts II and III: Strategic Requirements and Options," Appendix A, p. 23-26, Adelphi Papers, No. 170, IISS, 1974. Cities 1-70 data were obtained from G. Kemp Study: Cities 71-201 population data were obtained from: Harris, C. D., Cities of the Soviet Union, p. 15-19, Rand McNally & Company, 1970. Density and warhead Req's data were estimated using G. Kemp study as base-line reference. Total Soviet population - 250,900,000 people.

Rank	City	Pop. (000)	Cuml't Pop. Million	City Area Sq. Mi.	Thousands Per Sq. Mi. Density	% of Tot Pop	Warheads Required 50KT	Warheads Required 1MT	Cumulative Warheads 50KT	Cumulative Warheads 1MT
12	Donetsk	901	23.11	96	9.4	9.21	12	2	245	36
13	Chelyabinsk	897	24.0	96	9.3	9.56	12	2	257	38
14	Kazan	881	24.88	95	9.3	9.92	12	2	269	40
15	Dnepropetrovsk	875	25.76	94	9.3	10.30	12	2	281	42
16	Perm	854	26.61	92	9.3	10.61	11	2	292	44
17	Odessa	832	27.44	90	9.2	10.94	11	2	303	46
18	Omsk	830	28.27	89	9.3	11.30	11	2	314	48
19	Minsk	955	29.22	55	17.3	11.65	7	1	321	49
20	Rostov-naDonu	800	30.02	70	11.4	11.96	9	2	330	51
21	Volgagrad	797	30.81	86	9.3	12.30	11	2	341	53
22	Saratov	772	31.58	83	9.3	12.60	10	2	351	55
23	Ufa	755	32.33	81	9.3	12.90	10	2	361	57
24	Riga	743	33.07	99	7.5	13.20	12	2	373	59
25	Yerevan	791	33.86	90	8.7	13.50	11	2	384	61
26	Alma-Ata	753	34.61	63	11.9	13.80	8	1	392	62
27	Voronezh	655	35.27	70	9.3	14.06	9	1	401	63
28	Zaporozh'ye	638	35.91	67	9.5	14.31	8	1	409	64
29	Krasnoyarsk	618	36.53	66	9.4	14.60	8	1	417	65
30	L'vov	549	37.08	59	9.3	14.80	7	1	424	66
31	Krivoy Rog	553	37.63	60	9.2	15.00	7	1	431	68
32	Karaganda	534	38.16	57	9.4	15.21	7	1	438	68

Rank	City	Pop (000)	Cuml't Pop. Million	City Area Sq. Mi.	Thousands Per Sq. Mi. Density	% of Tot Pop	Warheads Required 50KT	Warheads Required 1MT	Cumulative Warheads 50KT	Cumulative Warheads 1MT
33	Yaroslavl'	534	38.69	57	9.4	15.42	7	1	445	69
34	Novokuznetsk	529	39.22	57	9.4	15.63	7	1	452	70
35	Khabarovsk	467	39.69	50	9.3	15.82	6	1	458	71
36	Irkutsk	450	40.14	48	9.4	16.00	6	1	464	72
37	Makeyevka	444	40.58	48	9.3	16.17	6	1	470	73
38	Ivanovo	437	41.02	47	9.3	16.34	6	1	476	74
39	Krasnodar	437	41.46	47	9.3	16.52	6	1	482	75
40	Barnaul	437	41.9	47	9.3	16.70	6	1	488	76
41	Vladivostok	426	42.33	46	9.3	16.87	6	1	494	77
42	Frunze	444	42.77	48	9.3	17.05	6	1	500	78
43	Zhdanov	412	43.18	44	9.3	17.21	5	1	505	79
44	Nizhniy Tagil	404	43.58	43	9.4	17.40	5	1	510	80
45	Tula	404	43.98	43	9.4	17.53	5	1	515	81
46	Izhevsk	403	44.38	43	9.4	17.70	5	1	520	82
47	Astrakhan	395	44.77	43	9.1	17.81	5	1	525	83
48	Kemerovo	390	45.16	42	9.3	18.00	5	1	530	84
49	Magnitogorsk	384	45.54	41	9.4	18.20	5	1	535	85
50	Lugansk	378	45.92	41	9.2	18.30	5	1	540	86
51	Gorlovka	368	46.28	40	9.2	18.44	5	1	545	87
52	Tallin	340	46.62	37	9.2	18.60	5	1	550	88
53	Penza	537	46.97	38	9.4	18.72	5	1	555	89

Rank	City	Pop. (000)	Cuml't Pop. Million	City Area Sq. Mi.	Thousands Per Sq. Mi. Density	% of Tot Pop	Warheads Required 50 KT	1MT	Cumulative Warheads 50KT	1MT
54	Dushanbe	388	47.36	42	9.2	18.87	5	1	560	90
55	Groznyy	355	47.71	38	9.3	19.01	5	1	565	91
56	Orenburg	350	48.06	38	9.2	19.16	5	1	570	92
57	Tomsk	348	48.41	37	9.4	19.30	5	1	575	93
58	Kalinin	341	48.75	37	9.4	19.43	5	1	580	94
59	Vilnyus	386	49.13	42	9.2	19.60	5	1	585	95
60	Ryazan'	334	49.46	36	9.3	19.71	4	1	589	96
61	Arkhangel'sk	332	49.79	36	9.3	19.84	4	1	593	97
62	Kirov	331	50.12	36	9.3	20.00	4	1	597	98
63	Kishinev	374	50.49	40	9.4	20.12	5	1	602	99
64	Nikolayev	322	50.81	35	9.2	20.25	4	1	606	100
65	Ul'vanovsk	315	51.12	34	9.3	20.40	4	1	610	101
66	Prokop'yervsk	311	51.43	33	9.4	20.49	4	1	614	102
67	Bryansk	309	51.74	33	9.4	20.62	4	1	618	103
68	Murmansk	308	52.05	33	9.3	20.74	4	1	622	104
69	Kaunas	305	52.36	33	9.2	20.86	4	1	626	105
70	Kaliningrad	341	52.70	37	9.2	21.00	5	1	631	106
71	Kursk	255	52.96	28	9.1	21.10	3	1	634	107
72	Lipetsk	253	53.21	28	9.1	21.21	3	1	637	108
73	Samarkand	248	53.46	27	9.1	21.31	3	1	640	109
74	Taganrog	245	53.72	27	9.1	21.41	3	1	643	110

Rank	City	Pop. (000)	Cuml't Pop. Million	City Area Sq. Mi.	Thousands Per Sq. Mi. Density	% of Tot Pop	Warheads Required 50KT	Warheads Required 1MT	Cumulative Warheads 50KT	Cumulative Warheads 1MT
75	Tyumen'	240	53.96	26	9.2	21.51	3	1	646	111
76	Ashkhabad	238	54.20	26	9.2	21.60	3	1	649	112
77	Gomel'	237	54.44	26	9.2	21.70	3	1	652	113
78	Kherson	235	54.68	26	9.2	21.80	3	1	655	114
79	Ulan-Ude	227	54.91	25	9.1	21.88	3	1	658	115
80	Dneprodrezhinsk	224	55.13	24	9.3	22.97	3	1	661	116
81	Simferopol'	223	55.35	24	9.3	22.06	3	1	664	117
82	Ordzhonikide	219	55.57	24	9.1	22.15	3	1	667	118
83	Chimkent	219	55.79	24	9.1	22.23	3	1	670	119
84	Orsk	215	56.01	24	9.1	22.32	3	1	673	120
85	Kurgan	215	52.23	24	9.1	20.81	3	1	676	121
86	Rybinsk	212	56.44	23	9.2	22.49	3	1	679	122
87	Ust'-Kamenogorsk	212	56.65	23	9.2	22.53	3	1	682	123
88	Tambov	211	56.86	23	9.2	22.66	3	1	685	124
89	Vladimir	211	57.07	23	9.2	22.74	3	1	688	125
90	Shakhty	209	57.28	23	9.1	22.82	3	1	691	126
91	Komsomol'sk-na-Amure	209	57.49	23	9.1	22.91	3	1	694	127
92	Kostroma	209	57.70	23	9.1	23.0	3	1	697	128
93	Orel	209	57.91	23	9.1	23.08	3	1	700	129
94	Sevastopol	209	58.12	23	9.1	23.16	3	1	703	130

Rank	City	Pop. (000)	Cuml't Pop. Million	City Area Sq. Mi.	Thousands Per Sq. Mi. Density	% of Tot Pop	Warheads Required 50KT	Warheads Required 1MT	Cumulative Warheads 50KT	Cumulative Warheads 1MT
95	Semipalatinsk	204	58.32	23	9.0	23.24	3	1	706	131
96	Chita	203	58.52	23	9.0	23.32	3	1	709	132
97	Vitebsk	203	58.72	23	9.0	23.40	3	1	712	133
98	Dzerzhinsh	201	58.92	22	9.1	23.48	3	1	715	134
99	Smolensk	196	59.11	21	9.2	23.56	2	1	717	135
100	Sochi	188	59.3	21	8.9	23.63	2	1	719	136
101	Poltava	184	59.48	20	9.2	23.71	2	1	721	137
102	Angarsk	183	59.66	20	9.2	23.77	2	1	723	138
103	Biysk	181	59.84	20	9.2	23.85	2	1	725	139
104	Kaluga	179	60.02	20	9.0	23.92	2	1	727	140
105	Zlatoust	178	60.20	20	9.0	24.71	2	1	729	141
106	Chernovtsy	178	60.38	20	9.0	24.06	2	1	731	142
107	Cheboksary	178	60.56	20	9.0	24.14	2	1	733	143
108	Stavropol	177	60.74	20	9.0	24.21	2	1	735	144
109	Tselinograd	176	60.91	20	9.0	24.23	2	1	737	145
110	Mogilev	176	61.09	20	9.0	24.35	2	1	739	146
111	Kirovabad	174	61.26	19	9.1	24.42	2	1	741	147
112	Petrozavodsk	171	61.43	19	9.0	24.48	2	1	743	148
113	Vologda	170	61.6	19	9.0	24.55	2	1	745	149
114	Syzran	169	61.77	19	9.0	24.62	2	1	747	150
115	Andizhan	169	61.94	19	9.0	24.69	2	1	749	151

Rank	City	Pop (000)	Cuml't Pop. Million	City Area Sq. Mi.	Thousands Per Sq. Mi. Density	% of Tot Pop	Warheads Required 50KT	Warheads Required 1MT	Cumulative Warheads 50KT	Cumulative Warheads 1MT
116	Kirovograd	168	62.11	19	9.0	24.62	2	1	747	150
117	Kopeysk	166	62.27	18	9.2	24.82	2	1	753	151
118	Petropavlovsk	166	62.43	18	9.2	24.88	2	1	755	154
119	Cherepovets	165	62.59	18	9.2	24.94	2	1	757	155
120	Makhachkala	165	62.75	18	9.2	25.00	2	1	759	156
121	Podolsk	163	62.91	18	9.1	25.07	2	1	761	157
122	Vinnitsa	163	63.07	18	9.1	25.14	2	1	763	158
123	Sterlitamak	162	63.23	18	9.1	25.20	2	1	765	159
124	Kamensk-Ural skiy	161	63.39	18	9.1	25.27	2	1	767	160
125	Novocherkassk	161	63.55	18	9.1	25.32	2	1	769	161
126	Kutaisi	159	63.71	18	8.9	25.39	2	1	771	162
127	Namangan	158	63.87	18	8.9	25.46	2	1	773	163
128	Dzhambul	155	64.02	17	9.1	25.52	2	1	775	164
129	Saransk	154	64.17	17	9.1	25.58	2	1	777	165
130	Pavlodar	154	64.32	17	9.1	25.64	2	1	779	166
131	Temirtau	150	64.47	17	9.1	25.70	2	1	781	167
132	Tolyatti	143	64.61	16	9.0	25.75	2	1	783	168
133	Rubtsovsk	142	64.75	16	9.0	25.81	2	1	785	169
134	Kramatorsk	141	64.89	16	9.0	25.86	2	1	787	170
135	Zhitomir	141	65.03	16	9.0	25.92	2	1	789	171

Rank	City	Pop. (000)	Cuml't Pop. Million	City Area Sq. Mi.	Thousands Per Sq. Mi. Density	% of Tot Pop	Warheads Required 50KT	Warheads Required 1MT	Comulative Warheads 50KT	Comulative Warheads 1MT
136	Sumy	140	65.17	16	9.0	25.97	2	1	791	172
137	Kadiyevka	139	65.31	15	9.2	26.03	2	1	793	173
138	Armavir	139	65.45	15	9.2	26.09	2	1	795	174
139	Chernigov	139	65.59	15	9.2	26.14	2	1	797	175
140	Leninsk-Kuznetskiy	138	65.73	15	9.2	26.20	2	1	799	176
141	Kiselevsk	138	65.87	15	9.1	26.25	2	1	801	177
142	Yoshka-Ola	137	66.01	15	9.1	26.31	2	1	803	178
143	Kremenchug	136	66.15	15	9.1	26.37	2	1	805	179
144	Aktyubinsk	135	66.29	15	9.0	26.42	2	1	807	180
145	Berezniki	134	66.42	15	9.0	26.47	2	1	809	181
146	Leninakan	133	66.55	15	9.0	26.52	2	1	811	182
147	Kolomna	131	66.68	15	8.9	26.58	2	1	813	183
148	Kokand	131	66.81	15	8.9	26.63	2	1	815	184
149	Klaypeda	131	66.94	15	8.9	26.68	2	1	817	185
150	Norilsk	129	67.07	14	9.2	26.73	2	1	819	186
151	Belgorod	129	67.20	14	9.2	26.78	2	1	821	187
152	Cherkassy	128	67.33	14	9.1	26.83	2	1	823	188
153	Novomoskovsk	126	67.46	14	9.0	26.89	2	1	825	189
154	Ussuriysk	124	67.58	14	8.9	26.94	2	1	827	190
155	Kommunarsk	124	67.7	14	8.9	26.98	2	1	829	191

Rank	City	Pop. (000)	Cuml't Pop. Million	City Area Sq. Mi.	Thousands Per Sq. Mi. Density	% of Tot Pop	Warheads Required 50KT	Warheads Required 1MT	Cumulative Warheads 50KT	Cumulative Warheads 1MT
156	Novorossiysk	123	67.82	14	8.9	27.03	2	1	831	192
157	Uralsk	123	67.94	14	8.9	27.08	2	1	833	193
158	Petropavlovsk-Kamchatskiy	123	68.06	14	8.9	27.13	2	1	835	194
159	Engel's	122	68.18	13	9.2	27.17	2	1	837	195
160	Miass	122	68.30	13	9.2	27.22	2	1	839	196
161	Bratsk	122	68.42	13	9.2	27.27	2	1	841	197
162	Serpukhov	121	68.54	13	9.2	27.32	2	1	843	198
163	Blagoveshchensk	121	68.66	13	9.2	27.37	2	1	845	199
164	Severodvinsk	121	68.78	13	9.2	27.40	2	1	847	200
165	Lisichansk	120	68.90	13	9.2	27.46	2	1	849	201
166	Bobruysk	120	69.02	13	9.2	27.51	2	1	851	202
167	Lyubertsy	120	69.14	13	9.2	27.55	2	1	853	203
168	Melitopol	119	69.26	13	9.1	27.60	2	1	855	204
169	Nalchik	119	69.38	13	9.1	27.65	2	1	857	205
170	Osh	119	69.50	13	9.1	27.70	2	1	859	206
171	Kerch'	118	69.62	13	9.1	27.75	2	1	861	207
172	Kustanay	118	69.74	13	9.1	27.80	2	1	863	208
173	Orekhovo-Zuyevo	117	69.86	13	9.0	27.84	2	1	865	209
174	Elektrostal	117	69.98	13	9.0	27.89	2	1	867	210

Rank	City	Pop. (000)	Cuml't Pop. Million	City Area Sq. Mi.	Thousands Per Sq. Mi. Density	% of Tot Pop	Warheads Required 50KT	Warheads Required 1MT	Cumulative Warheads 50KT	Cumulative Warheads 1MT
175	Anzhero-Sudzhensk	116	70.1	13	9.0	27.94	2	1	869	211
176	Belovo	116	70.22	13	8.9	27.98	2	1	871	212
177	Kovrov	116	70.34	13	8.9	28.04	2	1	873	213
178	Volzhskiy	114	70.46	13	8.9	28.08	2	1	875	214
179	Slavyansk	113	70.57	13	8.8	28.13	2	1	877	215
180	Mytishchi	112	70.68	12	9.2	28.17	2	1	879	216
181	Pskov	112	70.79	12	9.2	28.21	2	1	881	217
182	Grodno	111	70.90	12	9.2	28.26	2	1	883	218
183	Pervouralsk	110	71.01	12	9.2	28.30	2	1	885	219
184	Nikopol	110	71.12	12	9.2	28.34	2	1	887	220
185	Cheremkhovo	109	71.23	12	9.1	28.39	2	1	889	221
186	Novoshakhtinsk	107	71.34	12	9.0	28.43	2	1	891	222
187	Novokuybyshevsk	107	71.45	12	9.0	28.48	2	1	893	223
188	Novgorod	107	71.56	12	9.0	28.52	2	1	895	224
189	Maykop	106	71.67	12	8.8	28.56	2	1	897	225
190	Serov	104	71.78	12	8.8	28.61	2	1	899	226
191	Sumgait	104	71.88	12	8.8	28.65	2	1	901	227
192	Konstantinovka	103	71.98	11	9.2	28.69	2	1	903	228
193	Krasnyy Luch	102	72.08	11	9.2	28.73	2	1	905	229
194	Noginsk	102	72.18	11	9.2	28.77	2	1	907	230

Rank	City	Pop. (000)	Cuml't Pop. Million	City Area Sq. Mi.	Thousands Per Sq. Mi. Density	% of Tot Pop	Warheads Required 50KT	Warheads Required 1MT	Cumulative Warheads 50KT	Cumulative Warheads 1MT
195	Bukhara	102	72.28	11	9.2	28.81	2	1	909	231
196	Syktyvkar	102	72.38	11	9.2	28.85	2	1	911	232
197	Guryev	101	72.48	11	9.1	28.89	2	1	913	233
198	Batumi	100	72.58	11	9.1	28.93	2	1	915	234
199	Leninabad	100	72.68	11	9.1	28.97	2	1	917	235
200	Rovno	100	72.78	11	9.1	29.00	2	1	919	236
201	Chirchkik	100	72.88	11	9.1	29.04	2	1	921	237

APPENDIX C

U.S. CITIES OVER 1,000,000 INHABITANTS: CUMULATIVE POPULATION, CITY DENSITIES, AND POTENTIAL TARGETING DATA[100]

Rank	City	Pop (000)	Cuml't Pop. Million	City Area Sq. Mi.	Thousands Per Sq. Mi. Density	% of Tot Pop	Est. Warheads Required 50KT	1MT	5MT	25MT
1	New York, N.Y.	11571	11.57	2136	5.41	5.43	508	46	13	4
2	Los Angeles, Ca.	7036	18.61	4069	1.73	8.73	968	89	24	7
3	Chicago, Ill.	6974	25.58	3720	1.87	12.00	885	81	22	6
4	Philadelphia, Pa.	4818	30.39	3553	1.35	14.27	846	78	21	6
5	Detroit, Mich.	4199	34.58	1952	2.15	16.23	465	43	12	3
6	San Francisco, Ca.	3110	37.69	2478	1.25	17.69	590	54	15	4
7	Washington, D.C.	2861	40.55	2352	1.21	19.04	560	51	14	4
8	Boston, Mass.	2753	43.30	987	2.79	20.33	235	22	6	2
9	Pittsburg, Pa.	2401	45.7	3049	.78	21.46	726	67	18	5
10	St. Louis, Mo.	2363	48.06	4118	.57	22.56	980	90	25	7

[100]City population, city area and density data obtained from U.S. Bureau of the Census, County and City Data Book, 1972, p. 548-578, (A Statistical Abstract Supplement), U.S. Government Printing Office, Washington, D.C., 1973. Estimated warhead requirements data were obtained utilizing the scaling techniques derived in Appendix E, Table XV. Total U.S. population was assumed to be 213 million.

Rank	City	Pop. (000)	Cuml't Pop. Million	City Area Sq. Mi.	Thousands Per Sq. Mi. Density	% of Tot Pop	Est. Warheads Required 50KT	1MT	5MT	25MT
11	Baltimore, Md.	2071	50.13	2259	.91	23.54	538	49	14	4
12	Cleveland, Ohio	2064	52.19	1519	1.35	24.50	362	33	9	3
13	Houston, Tex.	1985	54.17	6286	.31	25.43	1497	138	38	10
14	Newark, N.J.	1857	56.02	701	2.65	26.30	167	15	4	1
15	Minneapolis, Minn.	1814	57.83	2107	.86	27.15	502	46	13	4
16	Dallas, Tex.	1556	59.38	4564	.34	27.88	1087	100	27	8
17	Seattle, Wash.	1424	60.80	4229	.33	28.54	1007	93	25	7
18	Anaheim, Ca.	1421	62.22	782	1.81	29.21	186	17	5	1
19	Milwaukee, Wis.	1403	63.62	1456	.96	29.87	347	32	9	2
20	Atlanta, Ga.	1390	65.01	1727	.80	30.52	411	38	10	3
21	Cincinnati, Ohio	1385	66.39	2150	.64	31.17	512	47	13	4
22	Paterson, N.J.	1358	67.74	427	3.18	31.80	102	9	3	1
23	San Diego, Ca.	1358	69.10	4262	.31	32.44	1015	93	26	7
24	Buffalo, N.Y.	1349	70.45	1591	.84	33.07	379	35	10	3
25	Miami, Fla.	1268	71.72	2042	.62	33.67	486	45	12	3
26	Kansas City, Mo.	1256	72.98	2767	.45	34.26	659	61	17	5
27	Denver, Colo.	1230	74.21	3660	.33	34.84	871	80	22	6
28	San Bernardino, Ca.	1141	75.35	27295	.04	35.37	6499	597	164	45
29	Indianapolis, Inc.	1111	76.46	3080	.36	35.89	733	67	19	5
30	San Jose, Ca.	1067	77.53	1300	.82	36.40	310	28	8	2
31	New Orleans, La.	1046	78.58	1975	.53	36.86	470	43	12	3

Rank	City	Pop. (000)	Cuml't Pop. Million	City Area Sq. Mi.	Thousands Per Sq. Mi. Density	% of Tot Pop	Est. Warheads Required 50KT	1MT	5MT	25MT
32	Tampa, Fla.	1012	79.59	1303	.77	37.37	310	29	8	2
33	Portland, Ore.	1007	80.59	3650	.27	37.84	869	80	22	6
34	Phoenix, Ariz.	968	81.56	9238	.10	38.29	2200	202	56	15
35	Columbus, Ohio	916	82.48	1494	.61	38.72	356	33	9	2
36	Providence, R.I.	914	83.40	679	1.34	39.15	162	15	4	1
37	Rochester, N.Y.	882	84.28	2316	.38	39.57	551	51	14	4
38	San Antonio, Tex.	864	85.14	1960	.44	39.97	467	43	12	3
39	Dayton, Ohio	852	85.99	1708	.49	40.37	407	37	10	3
40	Louisville, Ky.	827	86.81	908	.91	40.75	216	20	5	2
41	Sacramento, Ca.	804	87.61	3436	.23	41.13	818	75	21	6
42	Memphis, Tenn.	770	88.38	1363	.56	41.49	325	30	8	2
43	Fort Worth, Tex.	762	89.14	1607	.47	41.85	383	35	10	3
44	Birmingham, Ala.	739	89.88	2721	.27	42.19	648	60	16	5
45	Albany, N.Y.	722	90.6	2216	.32	42.54	528	49	13	4
46	Toledo, Ohio	692	91.29	1520	.45	42.86	362	33	9	3
47	Norfolk, Va.	681	91.97	678	1.00	43.18	161	15	4	1
48	Akron, Ohio	679	92.65	905	.75	43.49	215	20	5	2
49	Hartford, Conn.	663	93.31	672	.98	43.80	160	15	4	1
50	Oklahoma City, Okla.	642	93.95	2143	.30	44.11	510	47	13	4
51	Syracuse, N.Y.	637	94.59	2419	.26	44.40	576	53	15	4
52	Gary-Hammond, Ind.	633	95.22	937	.67	44.70	223	21	6	2

Rank	City	Pop (000)	Cuml't Pop. Million	City Area Sq. Mi.	Thousands Per Sq. Mi. Density	% of Tot Pop	Est. Warheads Required 50KT	1MT	5MT	25MT
53	Ft. Lauderdale, Fla.	620	95.84	1219	.50	44.99	290	27	7	2
54	Jersey City, N.J.	608	96.45	47	12.85	11	1	1	1	1
55	Greensboro, N.C.	605	97.06	2207	.27	45.57	525	48	13	4
56	Salt Lake City, Utah	558	97.62	1061	.52	45.83	253	23	6	2
57	Allentown, ~~N.J.~~ PA-	544	98.16	1086	.50	46.08	259	24	7	2
58	Omaha, Neb.	543	98.7	1537	.35	46.34	366	34	9	3
59	Nashville, Tenn.	541	99.24	1629	.33	46.59	388	36	10	3
60	Grand Rapids, Mich.	539	99.78	1420	.38	46.84	338	31	9	2
61	Youngstown, Ohio	537	100.32	1030	.52	47.34	245	23	6	2
62	Springfield, Conn.	530	100.85	534	.99	47.34	127	12	3	1
63	Jacksonville, Fla.	529	101.38	766	.69	47.59	182	17	5	1
64	Richmond, Va.	518	101.90	1196	.43	47.84	285	26	7	2
65	Wilmington, Del.	499	102.40	1165	.42	48.07	277	25	7	2
66	Flint, Mich.	498	102.90	1300	.38	48.31	310	28	8	2
67	Tulsa, Okla.	475	103.38	3781	.12	48.54	900	83	23	6
68	Orlando, Fla.	428	103.81	1215	.35	48.73	289	27	7	2
69	Fresno, Ca.	413	104.22	5968	.06	48.93	1421	131	36	10
70	Tacoma, Wash.	411	104.63	1676	.24	29.12	400	37	10	3
71	Harrisburg, Pa.	411	105.04	1624	.25	49.31	387	36	10	3

Rank	City	Pop. (000)	Cuml't Pop. Million	City Area Sq. Mi.	Thousands Per Sq. Mi. Density	% of Tot Pop	Est. Warheads Required 50KT	1MT	5MT	25MT
72	Charlotte, N.C.	409	105.45	1183	.34	49.50	282	26	7	2
73	Knoxville, Tenn.	400	105.85	1418	.28	49.69	338	31	9	2
74	Wichita, Kans.	389	106.34	2449	.15	49.92	583	54	15	4
75	Bridgeport, Conn.	389	106.63	193	2.01	50.06	46	4	1	1
76	Oxnard, Ca.	378	107.01	1863	.20	50.24	444	41	11	3
77	Lansing, Mich.	378	107.39	1702	.22	50.41	405	37	10	3
78	Mobile, Ala.	377	107.77	2818	.13	50.59	671	62	17	5
79	Canton, Ohio	372	108.14	576	.64	50.77	137	13	3	1
80	Davenport, Ill.	363	108.50	1704	.21	50.94	406	37	10	3
81	El Paso, Tex.	359	108.86	1058	.34	51.10	252	23	6	2
82	New Haven, Conn.	356	109.21	245	1.45	51.27	58	5	1	1
83	Tucson, Ariz.	352	109.56	9240	.03	51.44	2200	202	55	15
84	West Palm Beach, Fla.	349	109.91	2023	.17	51.60	482	44	12	3
85	Worchester, Mass.	344	110.25	474	.72	51.76	113	10	3	1
86	Wilkes-Barre, Pa.	342	110.59	888	.38	51.92	211	19	5	1
87	Peoria, Ill.	342	110.93	1803	.19	52.08	429	39	11	3
88	Utica, N.Y.	341	111.27	2658	.12	52.23	632	58	16	4
89	York, Pa.	340	111.61	1435	.23	52.40	342	31	9	2
90	Bakersfield, Ca.	329	111.94	8152	.04	52.55	1940	178	49	13
91	Little Rock, Ark.	323	112.26	1488	.21	52.70	354	33	9	2

Rank	City	Pop (000)	Cuml't Pop. Million	City Area Sq. Mi.	Thousands Per Sq. Mi. Density	% of Tot Pop	Est. Warheads Required 50KT	1MT	5MT	25MT
92	Columbia, S.C.	323	112.58	1465	.22	52.85	349	32	9	2
93	Lancaster, Pa.	320	112.90	946	.33	53.00	225	21	6	2
94	Beaumont, Tex.	318	113.22	1310	.24	53.15	312	29	8	2
95	Albuquerque, N.M.	316	113.54	1169	.27	53.31	278	26	7	2
96	Chattanooga, Tenn.	306	113.85	995	.30	53.45	237	22	6	1
97	Trenton, N.J.	304	114.15	228	1.33	53.59	54	5	1	1
98	Charleston, S.C.	304	114.45	2049	.14	53.73	488	45	12	3
99	Binghamton, N.Y.	303	114.75	2072	.14	53.87	493	35	12	3
100	Greenville, S.C.	300	115.05	1294	.23	54.01	308	28	8	2
101	Reading, Pa.	296	115.35	862	.34	54.15	205	19	5	1
102	Austin, Tex.	296	115.65	1012	.29	54.29	241	22	6	2
103	Shreveport, La.	294	115.94	1747	.16	54.43	416	38	11	3
104	Newport News, Va.	292	116.23	254	1.15	54.57	60	6	2	1
105	Madison, Wis.	290	116.52	1198	.24	54.70	285	26	7	2
106	Stockton, Ca.	289	116.81	1415	.20	54.84	337	31	8	2
107	Spokane, Wash.	287	117.1	1758	.16	54.98	418	38	10	3
108	Des Moine, Iowa	286	117.39	594	.48	55.11	141	13	3	1
109	Baton Rouge, La.	285	117.68	459	.62	55.25	109	10	3	1
110	Corpus Christi, Tex.	285	117.97	1531	.18	55.38	365	34	9	2
111	Fort Wayne, Ind.	280	118.25	671	.41	55.52	160	15	4	1

Rank	City	Pop. (000)	Cuml't Pop. Million	City Area Sq. Mi.	Thousands Per Sq. Mi. Density	% of Tot Pop	Est. Warheads Required 50KT	1MT	5MT	25MT
112	South Bend, Ind.	280	118.53	910	.30	55.64	217	20	5	2
113	Appleton, Wis.	277	118.81	1405	.19	55.78	234	31	8	2
114	Las Vegas, Nev.	273	119.08	7874	.03	55.91	1874	172	47	13
115	Rockford, Ill.	272	119.35	802	.33	56.03	191	18	5	1
116	Duluth, Minn.	265	119.62	7397	.03	56.16	1761	161	45	12
117	Santa Barbara, Ca.	264	119.88	2738	.09	56.28	652	60	16	5
118	Erie, Pa.	264	120.14	813	.32	56.40	194	18	5	1
119	Johnston, Pa.	263	120.40	1780	.14	56.52	424	39	11	3
120	Jackson, Miss.	259	120.66	1676	.15	56.64	399	37	10	3
121	Lorain, Ohio	257	120.92	495	.51	56.77	118	11	3	1
122	Huntington, W. Va.	253	121.17	1408	.18	56.88	335	31	8	2
123	Augusta, Ga.	253	121.42	1424	.17	57.00	339	31	8	2
124	Vallejo, Ca.	251	121.67	1613	.15	57.12	384	35	10	2
125	Salinas, Ca.	247	121.92	3324	.07	57.24	791	73	20	5
126	Pensacola, Fla.	243	122.16	1697	.14	57.35	404	37	10	3
127	Columbus, Ga.	239	122.40	1112	.21	57.46	265	24	7	2
128	Colorado Springs, Col.	236	122.64	2157	.10	57.57	514	47	13	4
129	Scranton, Pa.	234	122.87	454	.51	57.68	108	10	3	1
130	Ann Arbor, Mich.	234	123.1	711	.32	57.79	169	16	4	1
131	Evansville, Ind.	232	123.33	1065	.21	57.90	254	23	6	1

Rank	City	Pop. (000)	Cuml't Pop. Million	City Area Sq. Mi.	Thousands Per Sq. Mi. Density	% of Tot Pop	Est. Warheads Required 50KT	1MT	5MT	25MT
132	Lawrence, Mass.	232	123.56	208	1.11	58.01	50	5	1	1
133	Charleston, W. Va.	230	123.79	907	.25	58.11	216	20	5	2
134	Raleigh, N.C.	229	124.02	858	.26	58.22	204	19	5	1
135	Huntsville, Ala.	228	124.25	1348	.16	58.33	321	29	8	2
136	Hamilton, Ohio	226	124.48	471	.48	58.44	112	10	3	1
137	Saginaw, Mich.	220	124.70	814	.27	58.54	194	18	5	1
138	Eugene, Ore.	215	124.92	4562	.04	58.64	1086	100	277	8
139	Lowell, Mass.	213	125.13	152	1.39	58.74	36	3	1	1
140	Fayetteville, N.C.	212	125.34	654	.32	58.85	156	14	4	1
141	Waterbury, Conn.	209	125.55	217	.96	58.94	52	5	1	1
142	New London, Conn.	209	125.76	370	.56	59.04	88	8	2	1
143	Stamford, Conn.	206	125.97	121	1.71	59.14	29	3	1	1
144	Macon, Ga.	206	126.18	634	.32	59.24	151	14	4	1
145	Santa Rosa, Ca.	205	126.39	1604	.12	59.33	382	35	10	3
146	Kalamazoo, Mich.	202	126.59	562	.35	59.43	134	12	3	1
147	Montgomery, Ala.	201	126.79	1414	.14	59.52	337	31	9	2
148	Modesto, Ca.	194	126.98	1511	.12	59.62	360	33	9	3
149	Durham, N.C.	190	127.17	695	.27	59.70	165	15	4	1
150	Brockton, Mass.	190	127.36	162	1.17	59.79	39	4	1	1
151	Savannah, Ga.	187	127.55	445	.42	59.88	106	10	3	1

Rank	City	Pop. (000)	Cuml't Pop. Million	City Area Sq. Mi.	Thousands Per Sq. Mi. Density	% of Tot Pop	Est. Warheads Required 50KT	1MT	5MT	25MT
152	Salem, Ore.	187	127.74	1901	.09	59.97	453	42	11	3
153	Wheeling, W. Va.	182	127.92	945	.19	60.05	225	21	6	2
154	McAllen, Tex.	181	128.10	1543	.11	60.14	367	34	9	3
155	Roanoke, Va.	181	128.28	303	.59	60.22	72	7	2	1
156	Lubbock, Tex.	179	128.46	893	.20	60.31	213	20	5	1
157	Terre Haute, Inc.	175	128.64	1499	.11	60.39	357	33	9	2
158	Atlantic City, N.J.	175	128.82	569	.30	60.48	135	12	3	1
159	Lexington, Ky.	174	128.99	280	.62	60.56	67	6	2	1
160	Lima, Ohio	171	129.16	1305	.13	60.64	311	29	8	2
161	Racine, Wis.	171	129.33	337	.50	60.72	80	7	2	1
162	Galveston, Tex.	170	129.5	399	.42	60.79	95	9	2	1
163	Lincoln, Neb.	168	129.67	845	.19	60.87	201	18	5	1
164	Steubenville, Ohio	166	129.83	582	.28	60.95	139	13	4	1
165	Champaign, Ill.	163	129.99	1000	.16	61.03	238	22	6	2
166	Cedar Rapids, Iowa	163	130.15	717	.22	61.10	171	16	4	1
167	Springfield, Ill.	161	130.31	879	.18	61.18	209	19	5	1
168	Fort Smith, Ark.	160	130.47	3379	.04	61.25	805	74	20	6
169	Green Bay, Wis.	158	130.63	524	.30	61.32	125	11	3	1
170	Muskegon, Mich.	157	130.79	501	.31	61.40	119	11	3	1
171	Springfield, Ohio	157	130.95	402	.39	61.48	96	9	2	1
172	Topeka, Kans.	155	131.11	548	.28	61.55	130	12	3	1

Rank	City	Pop. (000)	Cuml't Pop. Million	City Area Sq. Mi.	Thousands Per Sq. Mi. Density	% of Tot Pop	Est. Warheads Required 50KT	1MT	5MT	25MT
173	Springfield, Mo.	153	131.26	677	.22	61.62	161	15	4	1
174	New Bedford, Mass	153	131.41	142	1.07	61.69	34	3	1	1
175	Fall River, R.I.	150	131.56	143	1.05	61.76	34	3	1	1
176	Waco, Tex.	147	131.71	1030	.14	61.83	245	23	6	2
177	Lake Charles, La.	145	131.86	1105	.13	61.90	263	24	7	2
178	New Britain, Conn.	145	132.01	87	1.67	61.97	21	2	1	1
179	Asheville, N.C.	145	132.15	657	.22	62.04	156	14	4	1
180	Amarillo, Tex.	144	132.29	1812	.08	62.10	431	40	11	3
181	Jackson, Mich.	143	132.43	698	.20	62.17	166	15	4	1
182	Portland, Maine	142	132.57	236	.60	62.23	56	5	1	1
183	Brownsville, Tex.	140	132.71	896	.15	62.31	213	20	5	1
184	Anderson, Ind.	138	132.85	453	.30	62.37	108	10	3	1
185	Provo-Orem, Utah	137	132.99	2014	.06	62.44	480	44	12	3
186	Altonna, Pa.	135	133.13	530	.25	62.50	126	12	3	1
187	Biloxi-Gulfport, Miss.	134	133.26	585	.23	62.56	139	13	4	1
188	Waterloo, Iowa	132	133.39	568	.23	62.62	135	12	3	1
189	Mansfield, Ohio	130	133.52	496	.26	62.68	118	11	3	1
190	Muncie, Ind.	129	133.65	398	.32	62.74	95	9	2	1
191	Petersburg, Va.	128	133.78	810	.15	62.80	193	18	5	1
192	Wichita Falls, Tex.	126	133.91	2449	.15	62.86	583	54	15	4

Rank	City	Pop. (000)	Cuml't Pop. Million	City Area Sq. Mi.	Thousands Per Sq. Mi. Density	% of Tot Pop	Est. Warheads Required 50KT	1MT	5MT	25MT
193	Ogden, Utah	126	134.04	581	.21	62.92	138	13	4	1
194	Decatur, Ill.	125	134.17	578	.21	62.99	138	13	3	1
195	Lynchburg, Va.	123	134.29	1024	.12	63.04	244	22	6	2
196	Vineland, N.J.	121	134.41	500	.24	63.10	119	11	3	1
197	Reno, Nev.	121	134.53	6375	.01	63.15	1518	139	38	11
198	Fargo, N.D.	120	134.65	2794	.04	63.21	665	61	17	5
199	Norwalk, Conn.	120	134.77	69	1.73	63.27	16	2	1	1
200	Pueblo, Colo.	118	134.89	2405	.04	63.38	65	6	2	1
201	Kenosha, Wis.	118	135.01	272	.43	63.38	65	6	2	1
202	Bay City, Mich.	117	135.13	447	.26	63.44	106	10	3	1
203	Sioux City, Iowa	116	135.25	1126	.10	63.49	268	25	7	2
204	Tuscaloosa, Ala.	116	135.37	1338	.08	63.55	319	29	8	2
205	Monroe, La.	115	135.49	638	.18	63.61	152	14	4	1
206	Abilene, Texas	114	135.6	1870	.06	63.66	445	41	11	3
207	Boise City, Idaho	112	135.71	1043	.10	63.71	248	23	6	2
208	Lafayette, La.	112	135.82	283	.39	63.76	67	6	2	1
209	Lafayette, Ind.	109	135.93	500	.21	63.81	119	11	3	1
210	Manchester, N.H.	108	136.04	140	.77	63.87	33	3	1	1
211	Lawton, Okla.	108	136.15	1087	.10	63.92	259	24	7	2
212	Wilmington, N.C.	107	136.26	1041	.10	63.97	248	23	6	2

Rank	City	Pop. (000)	Cuml't Pop. Million	City Area Sq. Mi.	Thousands Per Sq. Mi. Density	% of Tot Pop	Est. Warheads Required 50KT	1MT	5MT	25MT
213	Gainsville, Fla.	105	136.37	916	.11	64.02	218	20	6	2
214	Bloomington, Ill.	104	136.47	1173	.08	64.07	279	26	7	2
215	Tallahassee, Fla.	103	136.57	670	.15	64.11	160	15	4	1
216	Texarkana, Ark.	101	136.67	1514	.06	64.16	360	33	9	3

APPENDIX D

U.S. CITIES OVER 1,000,000 INHABITANTS TARGETABLE BY SOVIET CRUISE MISSILES[101]

City No.	City Rank	City	Pop. (000)	Cumulative Pop Millions	Percent of Total Population
1	1	New York, N.Y.	11571	11.57	5.43
2	2	Los Angeles, Ca.	7036	18.61	8.73
3	4	Philadelphia, Pa.	4818	23.43	11.00
4	6	San Francisco, Ca.	3110	26.54	12.46
5	7	Washington, D.C.	2861	29.4	13.80
6	8	Boston, Mass.	2753	32.15	15.09
7	9	Pittsburg, Pa.	2401	34.55	16.22
8	11	Baltimore, Md.	2071	36.62	17.19
9	13	Houston, Tex.	1985	38.61	17.92
10	14	Newark, N.J.	1857	40.47	19.00
11	16	Dallas, Tex.	1556	42.03	19.73
12	17	Seattle, Wash.	1424	43.45	20.04
13	18	Anaheim, Ca.	1421	44.87	21.06

[101] Includes all cities within 350 NM of coast, assuming missile is launched 200 NM off coast.

City no.	City Rank	City	Pop. (000)	Cumulative Pop Millions	Percent of Total Population
14	20	Atlanta, Ga.	1390	46.26	21.72
15	22	Paterson, N.J.	1358	47.62	22.36
16	23	San Diego, Ca.	1358	48.98	22.99
17	24	Buffalo, N.Y.	1349	50.33	23.63
18	25	Miami, Fla.	1268	51.60	24.23
19	28	San Bernardino, Ca.	1141	52.74	24.76
20	30	San Jose, Ca.	1067	53.81	25.26
21	31	New Orleans, La.	1046	54.86	25.76
22	32	Tampa, Fla.	1012	54.32	25.50
23	33	Portland, Ore.	1007	55.33	25.98
24	34	Phoenix, Ariz.	968	56.30	26.43
25	36	Providence, R.I.	914	57.22	26.86
26	37	Rochester, N.Y.	882	58.10	27.28
27	38	San Antonio, Tex	864	58.95	27.68
28	41	Sacramento, Ca.	804	59.75	28.05
29	42	Memphis, Tenn.	770	60.53	28.42
30	43	Fort Worth, Tex.	762	61.29	28.76
31	44	Birmingham, Ala.	739	62.03	29.12
32	45	Albany, N.Y.	722	62.75	29.46
33	47	Norfolk, Va.	681	63.43	29.78
34	48	Akron, Ohio	679	64.11	30.10

City No.	City Rank	City	Pop. (000)	Cumulative Pop Millions	Percent of Total Population
35	49	Hartford, Conn.	663	64.77	30.41
36	53	Fort Lauderdale, Fla.	620	65.39	30.70
37	54	Jersey City, N.J.	608	65.99	30.98
38	55	Greensboro, N.C.	605	66.61	31.27
39	57	Allentown, N.J.	544	67.15	31.53
40	61	Youngstown, Ohio	537	67.68	31.77
41	62	Springfield, Conn.	530	68.22	32.03
42	63	Jacksonville, Fla.	529	68.75	32.28
43	64	Richmond, Va.	518	69.27	32.52
44	65	Wilmington, Del.	499	69.77	32.75
45	68	Orlando, Fla.	428	70.19	32.95
46	69	Fresno, Ca.	413	104.22	33.15
47	70	Tacoma, Wash.	411	71.02	33.34
48	71	Harrisburg, Pa.	411	71.43	33.54
49	72	Charlotte, N.C.	409	71.84	33.73
50	73	Knoxville, Tenn.	400	72.23	33.91
51	75	Bridgeport, Conn.	389	72.63	34.10
52	76	Oxnard, Ca.	378	73.01	34.28
53	78	Mobile, Ala.	377	73.39	34.46
54	79	Canton, Ohio	372	73.76	34.63

City No.	City Rank	City	Pop. (000)	Cumulative Pop Millions	Percent of Total Population
55	82	New Haven, Conn.	356	74.12	34.80
56	83	Tucson, Ariz.	352	74.47	34.96
57	84	West Palm Beach, Fla.	349	74.82	35.12
58	85	Worchester, Mass.	344	75.16	35.29
59	86	Wilkes-Barre, Pa.	342	75.50	35.45
60	88	Utica, N.Y.	341	75.84	35.61
61	89	York, Pa.	340	76.18	35.76
62	90	Bakersfield, Ca.	329	76.50	35.92
63	91	Little Rock, Ark.	323	76.83	36.07
64	92	Columbia, S.C.	323	77.15	36.22
65	93	Lancaster, Pa.	320	77.47	36.37
66	94	Beaumont, Tex.	318	77.79	36.52
67	96	Chattanooga, Tenn.	306	78.10	36.67
68	97	Trenton, N.J.	304	78.40	36.81
69	98	Charleston, S.C.	304	78.70	36.94
70	99	Binghamton, N.Y.	303	79.00	37.09
71	100	Greenville, S.C.	300	79.30	37.23
72	101	Reading, Pa.	296	79.60	37.37
73	102	Austin, Tex.	296	79.90	37.51
74	103	Shreveport, La.	294	80.19	37.65

City No.	City Rank	City	Pop. (000)	Cumulative Pop Millions	Percent of Total Population
75	104	Newport News, Va.	292	80.48	37.78
76	106	Stockton, Ca.	289	80.77	37.92
77	107	Spokane, Wash.	287	81.06	38.06
78	109	Baton Rouge, La.	285	81.35	38.19
79	110	Corpus Christi, Tex.	285	81.64	38.33
80	114	Las Vegas, Nev.	273	81.91	36.46
81	117	Santa Barbara, Ca.	264	82.17	38.58
82	118	Erie, Pa.	264	82.43	38.70
83	119	Johnstown, Pa.	263	82.69	38.82
84	120	Jackson, Miss.	259	82.95	38.94
85	122	Huntington, W. Va.	253	83.20	39.06
86	123	Augusta, Ga.	253	83.45	39.18
87	124	Vallejo, Ca.	251	83.70	39.30
88	125	Salinas, Ca.	247	83.95	39.41
89	126	Pensacola, Fla.	243	84.19	39.53
90	127	Columbus, Ga.	239	84.43	39.64
91	129	Scranton, Pa.	234	84.66	39.75
92	132	Lawrence, Mass.	232	84.89	39.85
93	133	Charleston, W. Va.	230	85.12	39.96
94	134	Raleigh, N.C.	229	85.36	40.08

City No.	City Rank	City	Pop. (000)	Cumulative Pop Millions	Percent of Total Population
95	138	Eugene, Ore.	215	85.57	40.17
96	139	Lowell, Mass.	213	85.78	40.27
97	140	Fayetteville, N.C.	212	85.99	40.37
98	141	Waterburg, Conn.	209	86.20	40.47
99	142	New London, Conn.	209	86.61	40.66
100	143	Stamford, Conn.	206	86.82	40.76
101	144	Macon, Ga.	206	87.03	40.86
102	145	Santa Rosa, Ca.	205	87.24	40.96
103	147	Montgomery, Ala.	201	87.44	41.05
104	148	Modesto, Ca.	194	87.63	41.14
105	149	Durham, N.C.	190	87.82	42.17
106	150	Brockton, Mass.	190	88.01	41.32
107	151	Savannah, Ga.	187	88.20	41.41
108	152	Salem, Ore.	187	88.39	41.50
109	153	Wheeling, W. Va.	182	88.57	41.58
110	154	McAllen, Tex.	181	88.75	41.67
111	155	Roanoke, Va.	181	88.93	41.75
112	158	Atlantic City, N.J.	175	89.11	41.84
113	162	Galveston, Tex.	170	89.28	41.92
114	164	Steubenville, Ohio	166	89.45	41.99

City No.	City Rank	City	Pop. (000)	Cumulative Pop. Millions	Percent of Total Population
115	174	New Bedford, Mass.	153	89.60	42.07
116	175	Fall River, R.I.	150	89.75	42.14
117	176	Waco, Tex.	147	89.90	42.21
118	177	Lake Charles, La.	145	90.05	42.28
119	178	New Britain, Conn.	145	90.20	42.34
120	179	Asheville, N.C.	145	90.35	42.42
121	182	Portland, Maine	142	90.49	42.48
122	183	Brownsville, Tex.	140	90.63	42.55
123	186	Altoona, Pa.	135	90.77	42.62
124	187	Biloxi-Gulfport, Miss.	134	90.92	42.68
125	191	Petersberg, Va.	128	91.05	42.75
126	195	Lynchburg, Va.	123	91.18	42.81
127	196	Vineland, N.J.	121	91.30	42.86
128	197	Reno, Nev.	121	91.42	42.92
129	199	Norwalk, Conn.	120	91.54	42.98
130	204	Tuscaloosa, Ala.	116	91.66	42.93

APPENDIX E

NUCLEAR WEAPONS EFFECTS

A. BACKGROUND

The purpose of this appendix is to analyze the various factors contributing to effective employment of nuclear weapons capable of counterforce and countervalue roles and examine how these capabilities may be interpreted to derive realistic and credible numbers of warheads needed to develop a deterrence model. Some equations used in developing the deterrence model in this appendix were derived by Dr. William Reese, Department of Physics and Chemistry, for a Nuclear Weapons and Foreign Policy course taught at the Naval Postgraduate School, Monterey, California. Equations are derived using "ball-park" inputs with the intent of keeping the calculations simple to understand and yet to present data which are close to real-world results. Open-source literature data have been utilized for the calculations and, where no data were available, realistic estimates were made. This study will not address the detailed phenomenology involved in nuclear fission or fusion. A detailed explanation is presented in a publication entitled "The Effects of Nuclear Weapons" published by the Atomic Energy Commission.[102]

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[102]Glasstone, S., The Effects of Nuclear Weapons, United States Atomic Energy Commission, April 1962.

B. NUCLEAR BLAST EFFECTS

The amount of energy released by a one-kiloton (KT) nuclear explosion is equivalent to a conventional unit of energy release equal to one thousand short tons of TNT, or about 10^{12} calories, 1.15×10^{6} kilowatt hours or 1.8×10^{9} BTU's. This energy release is about the maximum energy generated in the largest nuclear power plants in a couple of hours, but in a nuclear explosion all energy is released in a few millionths of a second.

Once a nuclear chain reaction starts in a weapon, it goes to completion very rapidly as the dynamics of exponential growth take place. The released energy emerges in the form of blast and shock, thermal radiation and radiological effects. The exact partition of energy gained from a nuclear explosion depends on the weapon type (fission or fusion) and the surroundings at detonation, e.g., atmosphere, high altitude, underwater, etc. Fission-fusion weapons have a slightly higher fraction of energy associated with neutrons (which do not travel as far as gamma rays) than do fission weapons. At low altitude, the resulting energy released in a nuclear explosion is partitioned as 50% blast and shock, 35% thermal radiation and 15% radiological effects (5% initial and 10% delayed). Thus, for a 200KT weapon, the energy released will be in the form of 100KT blast and shock, 70KT thermal radiation and 30KT radialogical effects.

The major material damage caused by an air burst nuclear weapon is due to blast and shock which accompanies

the explosion. The majority of structures will suffer some damage from air blast when the overpressure in the blast wave is about one-half pound per square inch or more. The distance to which this overpressure level will extend depends on the yield or size of the explosion and the height of the burst. In considering the destructive effect of a blast wave, one of the important characteristics is the overpressure. The maximum overpressure value, i.e., at the blast wave (or shock) front, is called the "peak overpressure." As the blast wave travels in the air away from its source, the overpressure at the front steadily decreases, and the pressure behind the front falls off in a regular manner. After a short time, when the shock front has traveled a certain distance from the fireball, the pressure behind the front drops below that of the surrounding atmosphere and a so-called "negative phase" of the blast wave forms. During the negative (rarefaction or suction) phase, a partial vacuum is produced and air is sucked in, instead of being pushed away, as it is when the overpressure is positive. Forces accompanying the peak overpressure and negative phase cause most of the physical damage to structures. Blast and shock producing 60 pounds per square inch overpressure are fatal to 90% of the people exposed.

One of the important differences between a nuclear and a conventional high-explosive weapon is the large proportion of the energy of a nuclear explosion which is released in the form of thermal (or heat) radiation. Because of the

enormous amount of energy liberated per unit mass in a nuclear weapon, very high temperatures are attained. These are estimated to be several tens of million degrees, compared with a few thousand degrees in the case of a conventional explosion. As a consequence of these high temperatures, a considerable amount of energy is released in the form of electromagnetic radiation of short wave length. Initially, this is mainly in the soft X-ray region of the spectrum. However, X-rays are absorbed in the air, thereby heating it to high temperatures. This heated air, which constitutes the nuclear explosion fireball in turn radiates in a spectral region roughly similar to that of sunlight received at the earth's surface. It is the radiation (ultraviolet, visible and infrared) from the fireball, traveling at the velocity of light, which is received at distances from the explosion. The delay, therefore, between the emission of thermal radiation from the fireball and its arrival at a target miles away obviously is extremely short.

Although blast is responsible for most of the destruction caused by a nuclear air burst, thermal radiation will contribute to the overall damage by igniting combustible materials and thus starting fires in buildings or forests. These fires may spread rapidly among the debris produced by the blast. In addition, thermal radiation is capable of causing skin burns and eye injuries in exposed individuals. The extent of injury or damage caused by thermal

radiation or the chances of igniting combustible material depend to a large extent upon the amount of thermal radiation energy received by a unit area of skin, fabric, or other exposed material within a short interval of time. Thermal energy falling upon a given area from a specific explosion will decrease as the distance is increased from the explosion. Thermal energy is attenuated by the atmosphere due to absorption and scattering. Because of absorption, the thermal radiation, particularly that in the ultraviolet region, decreases markedly with increasing distance from the explosion. Some of the absorbed radiation is subsequently re-radiated, but the emission occurs with equal probability in all directions, so that the quantity proceeding in the direction of a given target is substantially reduced. Attenuation as a result of scattering, i.e., by the diversion of rays from their original paths, occurs with radiation of all wave lengths. The diversion of the radiation path due to scattering interaction leads to a somewhat diffuse, rather than direct, transmission of the thermal radiation. Thermal radiation having an intensity of 12 grams/cm^2 will cause third-degree burns.

Radioactive particles emitted from a nuclear explosion consist of Alpha, Beta and Gamma particles and neutrons. An Alpha particle is really a helium nucleus (two neutrons and two protons) and is the least harmful. A Beta particle is actually an electron and is the second most harmful to living tissue. A Gamma particle is a ray similar to a

light ray but has a shorter wave length (X-rays). Gamma rays and neutrons are by far the most damaging to living tissue and the ones usually considered when making radiation calculations.

In order to express the exposure of Gamma radiation (or X-rays) at any particular point, it is necessary to have a suitable unit of measurement. The unit which is specifically used in this connection os called the "Roentgen." By definition a Roentgen is defined as the quantity of Gamma radiation which will give rise to the formation of 2.08×10^{9} ion pairs per cubic centimeter of dry air.[103] More simply it is a measure of x-ray exposure.

The unit of measurement used to determine the amount (or dose) of radiation absorbed is called the "Rad." By definition, the Rad is the absorbed dose of any nuclear radiation which is accompanied by the liberation of 100 ergs of energy per gram of absorbing material.[104]

Although all ionizing radiations are capable of producing similar biological effects, the absorbed dose (measured in Rads), which will produce a certain effect, may vary appreciably from one type of radiation to another. This difference in behavior is expressed by means of the "Relative Biological Effectiveness" (RBE) of the particular nuclear radiation. The RBE of a given radiation is defined

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[103]Glasstone, op. cit., p. 375.

[104]*Ibid.*

as the ratio of the absorbed dose in Rads of Gamma radiation to the absorbed dose in Rads of the given radiation having the same biological effects. Another unit known as the "Roentgen Equivalent Man" (REM) is used to express energy absorption, but it does not take into account the biological effect of the particular nuclear radiation absorbed. The REM which is defined by

$$\text{Dose in REM's} = \text{RBE} \times \text{Dose in rads.} \qquad \text{(A-1)}$$

provides an indication of the extent of biological injury that would result from the absorption of nuclear radiation. Thus, a REM is a dose unit of biological effects. A dose of 1000 REM's is fatal to 90% of the people exposed.[105]

In summary a basic understanding of the difference between conventional and nuclear weapons is useful in becoming familiar with how they can be most effectively employed and the resultant effects. Blast and shock account for the majority of the damage and overpressures of 60 pounds per square inch will be fatal to 90% of the people exposed.

C. SCALING LAWS

In order to be able to calculate the characteristic properties of the blast wave from an explosion of any

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[105]Glasstone, op. cit., p. 595.

given energy, if characteristic values for another energy are known, appropriate scaling laws can be and are applied. With the aid of such laws it is possible to express the data for a large range of energies in a simple form. Theoretically, a given pressure will occur at a distance from an explosion that is proportional to the cube root of the weapon yield. Thus, cube root scaling may be applied over a wide range of explosion energies. According to this law, if R_1 is the range (or slant range) from a reference explosion of W_1 kilotons yield at which a certain overpressure or dynamic pressure is attained, then for any explosion of W_2 kilotons yield these same pressures will occur at a range R_2 given by

$$\frac{R_2}{R_1} = \left(\frac{W_2}{W_1}\right)^{1/3} \qquad \text{(A-2)}$$

It follows therefore that

$$R_2 = R_1 \left(\frac{W_2}{W_1}\right)^{1/3} \qquad \text{(A-3)}$$

If the reference explosion is conveniently chosen as having an energy yield of 1 KT so that $W_1 = 1$ it follows, therefore, from the equation that

$$R_2 = R_1 \times W_2^{\ 1/3} \qquad \text{(A-4)}$$

where R_1 refers to the distance from a 1-KT yield explosion. Consequently, if the range R_2 is specified, then the value of the yield explosion, W_2, required to produce a certain effect, e.g., a given peak overpressure, can be calculated. Alternatively, if the yield W_2 is specified, the appropriate range R_2 can be evaluated from equation (A-4).

Thermal damage is a bit more complicated to scale than blast and shock. However, if atmospheric attenuation is neglected (which is approximately valid except for the highest yields), thermal damage scales approximately by the square root of the weapon yield. It follows therefore that

$$R_2 = R_1 \times W_2^{\ 1/2} \qquad \text{(A-5)}$$

assuming that all factors are referenced to 1-KT yield as in equation (A-4). Utilizing these scaling laws Table XI was constructed.

Empirical data collected from the Japan incident are listed in Tables XII and XIII to display real-world damage capabilities and are utilized to derive a valid methodology to predict future weapon employment effects.

D. EMPIRICAL MODEL

The two Japan incidents provided useful empirical data to compute potential qualitative capabilities. These data can be utilized to develop a simple model to project potential damage to areas, knowing the yield and population

TABLE XI

SCALED NUCLEAR WEAPONS DATA

Effects

Radiological:	1000 REM's	90% fatalities
Blast and Shock:	60 PSI	90% fatalities
Thermal:	12 cal/cm^2	(third-degree burns)

DISTANCE AT WHICH EFFECTS OCCUR

W (KT)	Radiological	Blast and Shock	Therm
1	.42	.09	.25
10	.60	.19	.80
20	.76	.25	1.1
50	.85	.34	1.7
100	1.0	.42	2.4
200	1.15	.53	3.4
1000	1.5	.92	7.5
5000	1.8	1.57	15.0
25,000	2.2	2.7	33.5

Note: R = range (mi)

TABLE XII

HIROSHIMA DATA

Type Weapon:	Uranium - Fission
Yield:	Approximately 20 KT
Height of Burst:	1850 feet

Zone	Population	Density	Number Casualties	% Casualties	Injured
0 - 0.6 mi.	31,200	25,800	26,700	85%	3,000
0.6 - 1.6 mi.	144,800	22,700	39,600	27%	53,000
1.6 - 3.1 mi.	80,300	3,500	1,700	2.1%	20,000
Totals	256,300		68,000	26%	76,000

TABLE XIII

NAGASAKI DATA

Type Weapon: Plutonium Fission

Yield: Approximately 20 KT

Height of Burst: 1850 feet

Zone	Population	Density	Number Casulaties	% Casualties	Injured
0 - 0.6	30,900	25,500	27,200	88%	1,900
0.6 - 1.6	27,700	4,400	9,500	34%	8,100
1.6 - 3.1	115,200	15,700	1,300	1.1%	11,000
Total	173,800		38,000	22%	21,000

densities. In developing this model it is assumed that all persons inside R_{50} are casualties and all persons outside of R_{50} survive. R_{50} is the range from ground zero to a point where 50% casualties occur. It also assumes a scaling intermediate between thermal ($R \approx W^{1/2}$) and blast and shock ($R \approx W^{1/3}$) yielding an average scaling law ($R \approx W^{0.4}$). The range R_{50} for a 20KT weapon is assumed to be approximately 4/5 mile ($R_{50} \approx 4/5$ mi).

Utilizing these data for the model it follows that

$$R_{50} \approx 4/5 \left(\frac{W}{20}\right)^{0.4} \text{miles} \tag{A-6}$$

thus producing a lethal area of kill A_k

$$A_k = \pi R_{50}^2 = 2\left(\frac{W}{20}\right)^{0.8} \text{mi}^2 \tag{A-7}$$

Substituting 4/5 for ${R_{50}}^2$ it follows that

$$A_k = \pi (4/5)^2 = 2\left(\frac{W}{20}\right)^{0.8} \text{mi}^2 \tag{A-8}$$

If the population density is N_p (number of persons per square mile) the N_k (number killed) will be approximately

$$N_k \simeq 2N_p\left(\frac{W}{20}\right)^{0.8} \text{persons} \tag{A-9}$$

Comparing the empirical density, zone and per cent casualties data in the two events, it is significant to note that geography and physical protection rather than weapon characteristics account for most of the differences in damage. Different environments provide various degrees of protection and are listed in Table XIV.

TABLE XIV

NUCLEAR WEAPONS SHELTER PROTECTION DATA

Type Structure	R_{50} range (mi)
a. Persons in concrete buildings	0.12
b. Average shelter protection	0.8
c. Unprotected (outdoors)	1.3

Utilizing equations (A-6) and (A-8) the following table is constructed

TABLE XV

PROJECTED YIELD CASUALTIES

Yield (W)

	50 KT	200 KT	1 MT	5 MT	25 MT
R_{50} (mi)	1.15	2.0	3.8	7.3	13.9
A_k (mi^2)	4.2	12.6	45.7	166	600

These results indicate that for the typical compact Soviet city (40-60 mi^2) a warhead with a yield between one and two MT would be an ideal countervalue weapon. Warheads greater than five MT would be in excess of the yield required except for sprawling, low-density targets such as the majority of the cities in the U.S.

E. DETERRENT FORCE MODEL

In developing a deterrence model it is useful to understand that mutual assured destruction (MAD), as currently implemented, consists of a triad of sufficient strategic nuclear delivery forces (land-based ICBM's, submarine-launched ballistic missiles (SLBM's), and long-range heavy bombers) to inflict unacceptable damage on an aggressor even after absorbing a counterforce first strike from the aggressor. "Unacceptable damage" has been generally defined for computational and explanatory purposes as substantial damage to industrial capacity (e.g., 25 per cent destruction from blast effects alone), and substantial urban population deaths (e.g., the prompt death of one-fourth to one-third of all urban population).

Unacceptable damage is a term that requires quantitative and qualitative translation into numbers and types of warheads which will provide a credible deterrent force. This model assumes that 60 million casualties (approximately 25% of the Soviet population) would be unacceptable damage and that the number of weapons required to inflict such

damage would provide such a credible deterrent. Fifty million casualties is approximately 25% of the U.S. population. As a baseline force, warheads of approximately one MT will be considered which are typical of the POLARIS, MINUTEMAN I, SS-II and SS-N-6 and possibly the SS-N-3 (if the Soviets upgrade the engine and warhead to state-of-the-art technology and install it in the same sized airframe).

1. U.S.S.R. versus U.S.

Typical population densities for some U.S. major cities on a 40-square-mile basis are on the order of 15,000 people per square mile.[106] From Table XV, a one MT weapon A_k is 45.7 square miles; it follows that

$$\left(\frac{50 \times 10^6}{15 \times 10^3}\right)\left(\frac{1}{45.7}\right) = 73 \text{ weapons (1 MT each)} \qquad \text{(A-10)}$$

are required to inflict 50 million casualties on the U.S. However, all cities are not the same size, requiring higher numbers of weapons to gain the desired damage. Assuming that the most populated cities are targeted and the warheads are placed in the greatest density areas of each city, a reasonable target mix might be that given in Table XVI. To account for failures due to launch, guidance, warheads, etc., and considering the U.S.S.R.'s policy of using large numbers of weapons, 200 one-MT warheads possibly represents an acceptable deterrent for the Soviet Union in this model.

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[106] See Appendix C.

TABLE XVI

POTENTIAL SOVIET TARGETING SCENARIO

City	Warheads	Projected Casualties (Millions)
New York, N.Y.	5	6.75
Los Angeles, Ca.	3	3.50
Philadelphia, Pa.	3	2.0
Washington, D.C.	3	1.5
San Francisco, Ca.	3	1.75
Boston, Mass.	2	1.75
Pittsburg, Pa.	3	1.25
Baltimore, Md.	2	1.0
Newark, N.J.	2	1.0
Anaheim, Ca.	2	1.0
Paterson, N.J.	2	1.0
Buffalo, N.Y.	2	.5
Remaining 14 cities in top 25 (2 ea)	28	7.0
40 of the top remaining cruise missile targetable (2 ea)	80	20.0
Total One-MT Warheads	140	50 Million

Cities Struck: 66

Note: Cities listed in Appendix D were used in calculations.

2. U.S. versus U.S.S.R.

The problem is different in the Soviet Union because there are fewer large cities. Where cities exist, the densities are higher but on the whole, the country is more rural. Two hundred and one Soviet cities have populations of more than 100,000 inhabitants. This accounts for only 30% of the total population. Typical population densities for most major cities on a 40-square-mile basis are on the order of 10,000 persons per square mile. Computing these numbers it follows that

$$\left(\frac{60 \times 10^6}{10 \times 10^3}\right)\left(\frac{1}{45.7}\right) = 130 \text{ weapons (1 MT each)} \qquad \text{(A-11)}$$

are required to inflict 60 million casualties on the U.S.S.R. However, like the U.S. not all cities are the same size, requiring larger numbers of weapons. A reasonable targeting mix might be that given in Table XVII. To account for failures due to launch, guidance, re-entry, etc., 250 one-MT warheads possibly represents a minimum acceptable deterrent force for the U.S. in this model.

In summary, an acceptable deterrence force the the U.S. and U.S.S.R. is approximately 250 and 200 one-MT warheads, respectively. These numbers are capable of inflicting unacceptable damage. Then this number must remain after absorbing a first strike from the aggressor. The U.S. requires more warheads than the Soviets because potential

TABLE XVII

POTENTIAL U.S. TARGETING SCENARIO

City	Warheads	Projected Casualties (Million)
Moscow	6	6.0
Leningrad	4	3.2
Kiev	6	1.5
Cities 4 - 25 (2 ea)	44	16.8
Cities 26 - 66 (1 ea)	40	15.0
Cities 67 - 200 (1 ea)	135	17.5
Totals	235	60.6 (Million)

Cities Struck: 201

countervalue targeting asymmetries are more advantageous for the U.S.S.R. Soviet major cities are more dense than U.S. cities, but only 10 major cities have populations greater than one million as compared to the U.S. which has 33 cities with populations greater than one million. From the data displayed in Table XVII and Appendix B, it is evident that potential targeting for casualties greater than 60 million (25% of the population) would require increasingly larger numbers of weapons, eventually approaching an exponential growth rate.

These computed numbers of warheads are commonly referred to as second-strike weapons which survive the first strike and are capable of inflicting unacceptable damage on the aggressor and are utilized in the deterrence model developed in Chapter III. It must be emphasized that this is a "pure" model which does not consider the large megatonnage the Soviets have available in their SS-9 missiles which, if considered, would decrease the number of weapons needed to inflict unacceptable damage on the U.S. It is also important to emphasize that the quantities obtained from this model are crude estimates of the number of delivered warheads required to achieve adequate deterrence and that the model assumes an undefended defense posture.

3. Targeting Factors

To determine a more accurate force level, the following items must be included:

(a) Defense (ABM or Air),

(b) Civil defense,

(c) System reliabilities,

(3) Losses to a possible first strike.

When considering active defense the delivery capability must be increased to account for the number of warheads which will not arrive at their targets. Missile defenses are quite limited in number as a result of the SALT negotiations, which allow 100 interceptor missiles at each of two sites. These interceptor missiles would be a factor when launching at targets within the ABM defense area. Assuming the ABM-system protecting Moscow was capable of destroying 100% of the incoming RV's launched, 101 warheads would be required for launch against Moscow before one would actually reach the city. The probability that the Moscow ABM system is capable of attaining these operational standards is probably quite remote. Probability figures approaching 50% may be more realistic, assuming a saturated attack.

When considering bomber defenses, the probability of the aircraft penetrating and arriving over the target is much lower than ballistic missile penetration probability due to an extensive Soviet anti-bomber defense system. Bombers are capable of delivering more than one warhead; hence aircraft successfully penetrating the defenses would be capable of striking more than one target. Projected

bomber losses must be included in the total strategic force requirements.

Since deterrence is dependent on inflicting casualties, civil defense measures implemented by a country can cause a great increase in the number of warheads required. These defense measures significantly reduce the lethal radius of each weapon. Table XIV listed the R_{50} ranges of .12 mi for a concrete shelter as compared to 1.3 mi for no protection. Scaling the concrete shelter ranges and utilizing them in the deterrence model computations increases the number of warheads required by almost 40 times that needed assuming a no-protection status. Implementing a civil defense program to protect the industrial base would be much more difficult and expensive than a population defense program. The probability that the Soviets are employing a complete physical industrial base defense program is probably small. However, a limited defense program would require an increase in deliverable warheads to counter that degree of protection attained.

System reliabilities and losses caused by the opposing side launching a first strike involve complex calculations and require the development of new models which can predict probabilities that a warhead will be successfully launched and accurately delivered on a designated target. The contributing factors include: single shot kill probability (SSKP); reliability, terminal kill

probability, and targeting; reprogramming; and CMP and EMT, which will be addressed separately. Davis and Schilling's article[107] will be utilized to develop the SSKP; reliability, terminal kill probability, and targeting; and reprogramming models.

F. SINGLE SHOT KILL PROBABILITY

SSKP is the probability that a single warhead can destroy a target. The probability that a single, reliable warhead can be expected to destroy a given target is a function of the destructive effort of the warhead on the target and the accuracy of the warhead. The destructive effect of a warhead on a given target is expressed in terms of its lethal radius (LR): the distance from the point of the explosion that the warhead will be able to destroy the target. The accuracy of a warhead is expressed in terms of its Circular Error Probability (CEP), the radius of the circle centered on the target within which the warhead has a 50-50 chance of landing. If the distribution of shots in repeated firings is approximately circular normal, the formula for calculating SSKP (if CEP and LR are expressed

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[107]Davis, L. E. and Schilling, W. R., "All You Ever Wanted to Know about MIRV and ICBM Calculations but Were Not Cleared to Ask," Journal of Conflict Resolution, v. 17, No. 2, p. 210, June 1973.

in the same units) is[108]

$$SSKP = 1 - e^{-0.69315\left(\frac{LR}{CEP}\right)^2}$$

or

$$SSKP = 1 - .5^{\left(\frac{LR}{CEP}\right)^2} \qquad \text{(A-12)}$$

In order to use the formula cited above to calculate the SSKP of a single, reliable warhead against a missile silo, or any other target, the LR of the warhead must be determined. The LR of a nuclear explosion is a function of the yield of the warhead, the hardness of the target, and the altitude of the burst. Warhead yield is expressed as previously mentioned in KT or MT. Target hardness is expressed in terms of the pounds per square inch (psi) of pressure over normal atmospheric pressure required to destroy the target.

There are several ways to calculate the LR for warheads used against hard targets like missile silos. "The Effects of Nuclear Weapons"[109] publication contains a graph showing the distances from ground zero that a one-KT surface burst will produce peak overpressures from .1 psi to 1000 psi.

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[108]Davis and Schilling, op. cit., p. 211.

[109]Glasstone, op. cit., p. 135.

Applying cube root scaling laws the LR for any other yield of warhead (Y in kilotons) against a target of the same hardness can be calculated by the formula

$$LR_y = LR_{1Kt} \times Y^{1/3} \qquad \text{(A-13)}$$

For example, to determine the LR of a five-MT warhead against a target that could be destroyed by 300 psi, extrapolate from the graph the distance where a one-KT explosion will produce 300 psi (which is about 220 feet) and utilize formula (A-13) for obtaining the scaling solution.

$$LR_{5MT} = 220 \times 5000^{1/3} = 3762 \text{ feet } (.619 \text{ NM}) \qquad \text{(A-14)}$$

This LR value can then be substituted in the SSKP formula (A-12) to find the SSKP for a five-MT warhead. For this example, a CEP of .25 nm against a 300 psi target is used.

$$SSKP = 1 - .5^{\left(\frac{.619}{.25}\right)^2} \qquad \text{(A-15)}$$

The result of this calculation yields a SSKP of .985. SSKP calculations are utilized to determine probabilities of destroying hard targets which are either countervalue or counterforce in nature. Countervalue targets could include hardened command and control sites and high

economic value targets which, when removed in a surgical manner, could demonstrate resolve. Weapons capable of obtaining high SSKP would obviously enable a nation greater foreign policy alternatives.

G. RELIABILITY, TERMINAL KILL PROBABILITY, AND TARGETING

The formula for SSKP is based on the assumption that the warhead will arrive at the target and explode. In reality, this is not always the case. There are many factors which contribute to possible failure in a missile system between firing the missile and actual detonation of the warhead on the target. In order to determine the actual probability of kill, a value must be assigned to the Overall Reliability (OAR) of the missile system. The OAR represents an estimate of the probability that first the missile and then the warhead will function properly during the course of the entire flight. OAR is the product of the individual probabilities that the system will not malfunction during each stage of countdown and launch (Launch Reliability) and during each stage of flight including: the boost phase, separation of the re-entry vehicle, penetration of the atmosphere, and the detonation of the warhead. Assume, for example, a missile system with the following characteristics: a .95 probability of a successful countdown and launch; a .95 probability of successful separation following boost; .95 probability of successful penetration

following separation; and a .95 probability of successful detonation following penetration. The overall reliability of such a system would be $.95^5$ or .773.

To compute the composite probability of an individual warhead actually destroying a target (Terminal Kill Probability or TKP), the SSKP is multiplied by the OAR of the missile system:[110]

$$TKP = SSKP \times OAR \qquad \text{(A-16)}$$

For example, if the SSKP of the warhead was .94 and the OAR was .773, the TKP would be .94 x .773 = .727.

Once the TKP of a single warhead is determined, the probability of destroying the target if more than one warhead is fired at the same target can be calculated. Assume, for example, that two warheads (one with a TKP of .65 and one with a TKP of .75) are fired at the same target. The probability of the target surviving a hit from the first warhead is $(1\text{-}TKP_1)$ or (1-.65), and the probability of the target surviving a hit from the second warhead is $(1\text{-}TKP_2)$ or (1-.75). The probability of the target surviving the two hits independently is

$$(1\text{-}TKP_1) \times (1\text{-}TKP_2)$$

or

$$(1\text{-}.65) \times (1\text{-}.75) = .0875.$$

[110]Davis and Schilling, op. cit., p. 217.

The probability of kill of the two warheads (PK_{2wh}) is thus (1-.0875) or .913.

In the event that the warheads being fired at the same target have the same TKP, the probability that the target will survive a hit from two warheads if $(1\text{-TKP})^2$ and the

$$PK_{2wh} = 1 - (1\text{-TKP})^2 \tag{A-17}$$

In the case of "n" warheads (with equal TKPs), the probability of kill can be calculated with the formula[111]

$$PK_{n_{wh}} = 1 - (1\text{-TKP})^n \tag{A-18}$$

The results of targeting an entire missile force can be calculated once the Terminal Kill Probabilities for one or "n" warheads have been computed.

Assume, for example, 1500 warheads (with equal TKPs) are fired at 1000 targets, the SSKP for each warhead is .94 and all five reliability factors are .95. Solving the problem, let x = the number of targets that receive one warhead and y = the number of targets that receive two warheads.

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[111]Davis and Schilling, op. cit., p. 217.

It follows then that

$$\begin{array}{rcl} x + y & = & 1000 \text{ targets} \\ x + 2y & = & 1500 \text{ warheads} \\ \hline y & = & 500 \\ x & = & 500 \end{array}$$

Hence 500 targets get one warhead each and 500 targets get two warheads each. Computing the TKP_{1wp}, utilizing formula (A-16)

$$TKP_{1wp} = (.94)(.95)^5 = .727 \tag{A-19}$$

Determining the TKP_{2wp} is obtained by utilizing formula (A-17) and the resultant number from (A-19)

$$TKP_{2wp} = 1 - (1-.727)^2 = .926 \tag{A-20}$$

Hence, to determine the number of targets killed by 1500 warheads, the following computations must be made:

$$\begin{array}{rcr} .727 \times 500 \text{ (1 warhead targets)} & = & 363 \\ .926 \times 500 \text{ (2 warhead targets)} & = & \underline{463} \\ & & 826 \end{array} \tag{A-21}$$

yielding 826 target kills out of the 1000 targets struck by 1500 warheads.

H. REPROGRAMMING

In a situation in which the number of attacking warheads is greater than the number of targets, the number of targets destroyed could be increased if the attacking power could identify those missiles that had malfunctioned sometime during the launch or flight (and whose warheads would therefore never reach their intended target) and could assign other missiles to replace those that had failed. This would improve the chances that all targets would receive at least one warhead and thereby increase the efficiency of the attack. This strategy for allocating warheads to targets requires that the attacker not fire all of his missiles at once. Some warheads must be held in reserve to replace those known to have failed. The ability to identify missiles that have failed and to reprogram other missiles to take their place is called reprogramming, or shoot-look-shoot.

In order to calculate the effect of a reprogramming system, it is necessary to break down the overall reliability into two components: reprogrammable reliability (RR) and nonreprogrammable reliability (NRR). RR expresses the probability that the missile will perform correctly during that part of launch and flight in which failures can be identified, and (1-RR) the probability that the missile will fail during the time failures can be identified.. Similarly, NRR expresses the probability that the missile

will perform correctly during that part of the flight when failures cannot be identified, and (1-NRR) the probability that the missile will fail during that time. RR x NRR always equals OAR. In calculating the effects of an attack using reprogramming, it is useful to keep in mind that since all known failures have been replaced, the TKP of each warhead successfully going toward a target is calculated by multiplying the SSKP by the NRR.[112]

$$TKP = SSKP \times NRR \qquad (A\text{-}22)$$

To illustrate the effect of an attack employing a reprogramming, the data used in the previous example will be utilized again so a comparison can be made between the two procedures. Assume that the .773 OAR of the missile system is the product of five reliabilities: .95 probability of successful countdown and launch; .95 probability of successful boost after launch; .95 probability of successful separation after boost; .95 probability of successful penetration after separation; and .95 probability of successful detonation after penetration. Assume further that information is available for all failures during countdown, launch, boost, and separation. The RR of the system would then be $.95^3 = .857$, and the NRR would be $.95^2 = .902$. Remembering that there were 1000 targets

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[112] Davis and Schilling, op. cit., p. 220.

and 1500 warheads, the number of warheads which survive the first three stages can be calculated

$$(.95)^3(1500) = 1285 \qquad \text{(A-23)}$$

Solving the problem, let x = the number of targets that receive one warhead and y = the number of targets that receive two warheads. It follows that

$$\begin{aligned} x + y &= 1000 \text{ targets} \\ \underline{x + 2y} &\underline{= 1285 \text{ warheads}} \\ y &= 285 \\ x &= 715 \end{aligned}$$

Hence 285 targets get two warheads each and 715 targets get one warhead each. Now calculating the number of warheads surviving using formula (A-21)

$$\text{TKP} = \text{NRR} \times \text{SSKP}$$

or

$$\text{TKP}_1 = (.95)^2 \times (.94) = .848 \qquad \text{(A-24)}$$

and computing the TKP for targets programmed to receive two warheads each

$$\text{TKP}_2 = 1 - (1-.848)^2 \qquad \text{(A-25)}$$

or

$$\text{TKP}_2 = .977$$

The number of targets killed can now be calculated

$$\begin{array}{lll} .848 \times 715 & \text{(1 warhead targets)} = & 607 \\ .977 \times 285 & \text{(2 warhead targets)} = & \underline{278} \\ & & 885 \end{array} \qquad \text{(A-26)}$$

Comparing the A-21 and A-26 results, reprogramming has increased the number of target kills by 59, approximately 6%, which is significant.

In summary, a reprogramming system, by providing information on a certain percentage of failures in an attack, enables the attacker to reprogram reserve missiles to replace these known failures.

I. ELECTROMAGNETIC PULSE

A phenomenon associated with a nuclear explosion (and one that is relevant for a counterforce weapon) is the so-called Electromagnetic Pulse (EMP). A nuclear explosion ionizes the atoms of the atmosphere in its immediate vicinity, giving rise to electric and magnetic fields having an intensity of 100,000 volts per meter^2 (which is 1000 times more intense than a radar beam)[113] which is sufficient to penetrate an unshielded silo and destroy the complex and delicate electronic equipment of a missile and its launching facilities.

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[113]Defense Nuclear Agency, DNA EMP Awareness Course, p. 1, August 1971.

J. FRATRICIDE

The EMP, the movement of the air mass near the explosion, the large amounts of debris that the explosion causes to rise rapidly into the upper atmosphere, and the persistently high level of radioactivity emanating from the expanding fireball combine to create an effect, known as "interference," "screening" or "fratricide." Fratricide makes it difficult to deliver a re-entry vehicle to the same point soon after an earlier one has arrived and detonated. As the second re-entry vehicle enters the atmosphere near the point where the first exploded, it encounters high densities of dust that can cause its protective shield to burn prematurely, or it can be deflected off-target by the violent winds that persist in the area for considerable periods of time, or, if it arrives a few seconds after the first weapon, it could even be destroyed by EMP or the nuclear radiation emanating from the fireball. This phenomenon could have a significant impact on all warheads having on-board computers. The EMP electromagnetic spectrum is broad and extends from very low frequencies into the UHF band causing interferences with all electronics equipment including command and control systems.

K. COUNTER MILITARY POTENTIAL

The lethality of a nuclear weapon against a hardened target is a function of the warhead's yield and accuracy.

Lethality can be mathematically expressed as follows:[114]

$$CMP = \frac{Y^{2/3}}{(CEP)^2}\, n \qquad \text{(A-27)}$$

where CMP is an expression of the lethality, Y is the yield in MT, CEP is the accuracy in NM and n is the number of warheads. By inspection it is evident that as the CEP is decreased, the lethality is increased and the probability that the warhead can destroy a hard target is also increased. Lethality increases much more rapidly with an improvement in accuracy than with an increase in yield. Once the accuracy is such that the CEP is smaller than the radius of the crater excavated by the explosive force of the weapon, the lethality has reached its maximum value, since any silo within such a crater would certainly be destroyed. The lethality factor can be used to describe both the lethality of a warhead and the lethality needed to destroy a target. Thus it is possible to calculate the lethality required to destroy all the offensive-missile silos in the U.S.S.R. or U.S. with a given probability. The lethality times the number of warheads determines the total lethality potential a country can deliver. Additional parameters such as the reliability of re-entry vehicles,

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[114]Tsipis, K., "The Calculus of Nuclear Counterforce," Technology Review, v. 77, p. 38, October/November 1974.

and the timing of the arrival against a silo must be considered in making the calculations. The calculations required to derive these numbers are very complex and will not be addressed in this study, but it is useful to realize the relationship between the warhead yield and the accuracy of the re-entry vehicle.

L. EQUIVALENT MEGATONNAGE

Equivalent megatonnage (EMT) is a mathematical expression of a country's countervalue force potential. EMT can be expressed as follows:

$$EMT = Y^{2/3}\ n \qquad \text{(A-28)}$$

where Y is the yield and n is the number of warheads. Unlike CMP, the warhead accuracy is not a factor in determining the equivalent megatonnage because accuracy is not critical when striking countervalue targets. Large yields increase a country's EMT and the SS-9 provides the Soviets with that capability. Yield times the number of warheads in a country's force provides a measure of the potential countervalue capability. The Soviets' large throw weight advantage enables them to potentially launch more than twice the EMT the U.S. can launch.

APPENDIX F

THEORETICAL DETERRENCE MODEL

The mutual assured destruction framework has led us to the position where our strategic weapons policy is partly a result of a mathematical model of force design. Within this model exist a series of points or areas in which the numbers and types of missiles the United States and the Soviet Union should maintain for stable deterrence. A deterrence model can be graphically represented.[115] See Figure 5.

The United States and the Soviet Union represent exponents in a two-party duel which will be represented by X and Y, respectively. Should X possess N_x missiles of a particular type and Y possess N_y missiles of the same basic type, this situation can be represented by a point P on a graph, as depicted in Figure 5, with certain cartesian coordinates (N_x, N_y).

The deterrence model will be developed using the number of land-based ICBM missiles the United States and the Soviet Union had deployed at the time of the Interim Agreement of May 27, 1972. It is believed the Soviets about 1618 and the U.S. 1054. As previously discussed,

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[115]Legault, A. and Lindsey, G., <u>The Dynamics of the Nuclear Balance</u>, p. 167, Cornell University Press, 1974.

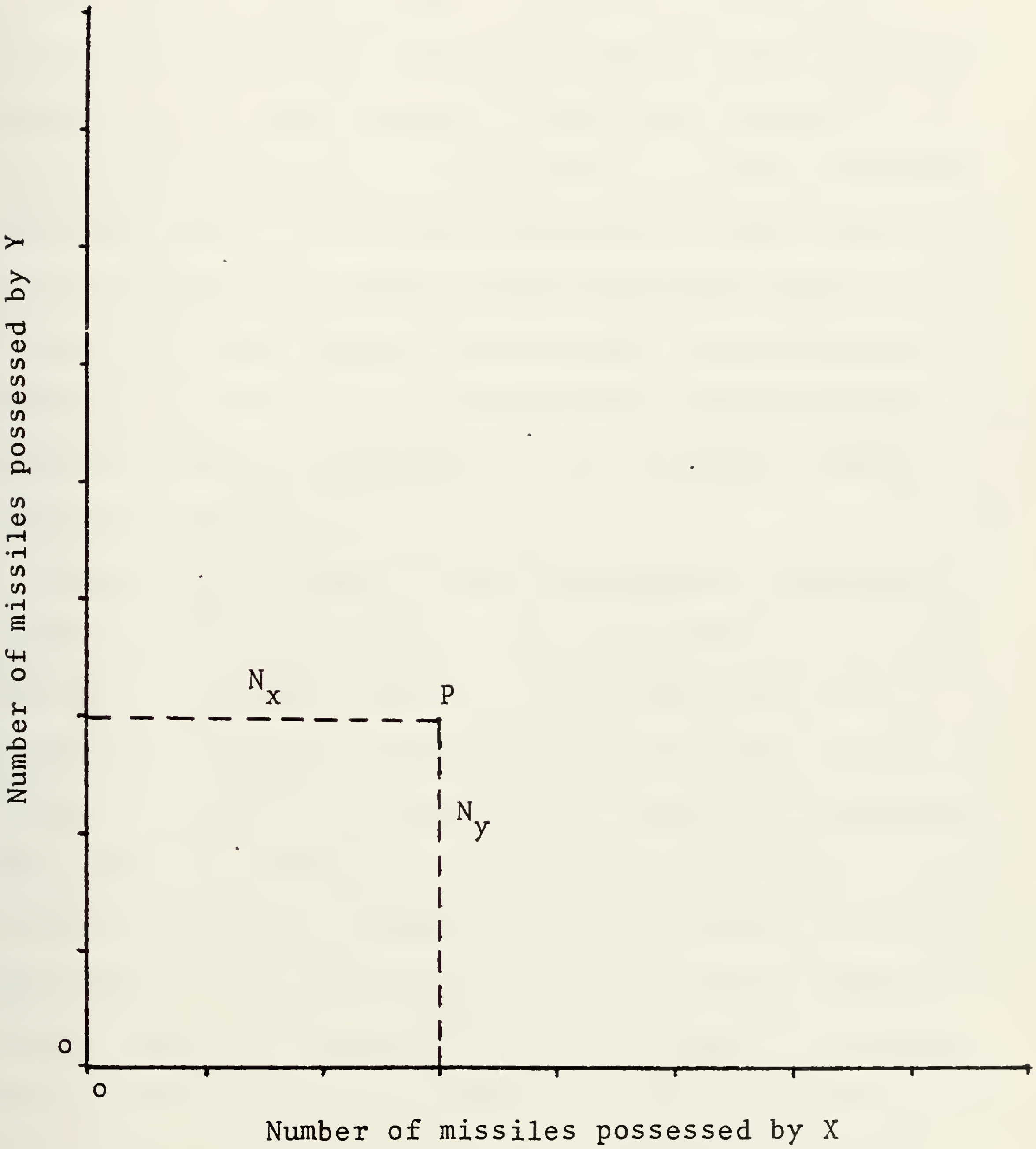

Figure 5. Coordinates indicating the number of missiles possessed by X and Y

deterrence depends on a nation's ability to deliver unbearable or unacceptable damage, even after absorbing a counterforce first strike. In order to develop a mathematical model of deterrence, numbers must be placed on adjectives. What damage is considered unbearable or unacceptable for a country to absorb? Secretary McNamara indicated that in the case of the Soviet Union, destruction of one-fourth to one-third of her population and one-half of her industrial capacity would serve as an effective deterrent. Such a level of destruction would probably represent adequate punishment to any twentieth century industrial nation.[116]

Legault and Lindsey[117] have developed an algebraic expression for a deterrence model which will be utilized for this discussion. This is a pure model derived to aid and simplify the understanding of deterrent force theory. Chapter III-B amplifies this model by employing more realistic numbers of missiles which are needed to inflict unacceptable damage. U_y is a threshold, representing the number of Y's missiles which could inflict damage on X's cities, which is considered intolerable for X, and beyond which X would be deterred from any further offensive action for fear of provoking such injury. Similarly, U_x is a

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[116]McNamara, loc. cit.

[117]Legault and Lindsey, op. cit., p. 170-188.

threshold representing the damage X's missiles could inflict on Y's cities, which is considered intolerable for Y. The level of damage either side cannot bear is that level corresponding to the destructive power of U_x or U_y's missiles used in a counter city attack.

The deterrence model proposes that the two thresholds U_x and U_y need not necessarily be the same number of missiles. One nation may be prepared to face greater sacrifices than the other, influencing the "unacceptable damage" threshold the other may perceive as unbearable. Hence X and Y may not make the same estimates of U_x and U_y. A key point which must be emphasized in building this model is that it is X's estimate of what Y perceives is unacceptable damage to X and U_y is the number of missiles required to inflict that perceived unbearable damage. Similarly, U_x is the number of missiles required to inflict what X perceives as unacceptable damage to Y and U_x is the number of missiles required to inflict that damage.

Figure 6 shows a rectangle $OU_x\ AU_y$ with sides $N_x = 0$, $N_y = 0$, $N_x = U_x$, and $N_y = U_y$. Any point such as Po which is inside this rectangle represents a situation in which there is no deterrence in either direction, since $N_x < U_x$ and $N_y < U_y$. There obviously must be degrees of deterrence, so that if X expected to have his cities hit by $(U_y\text{-}1)$ missiles, he would be "nearly deterred." In constructing this simple model partial deterrence is neglected and the

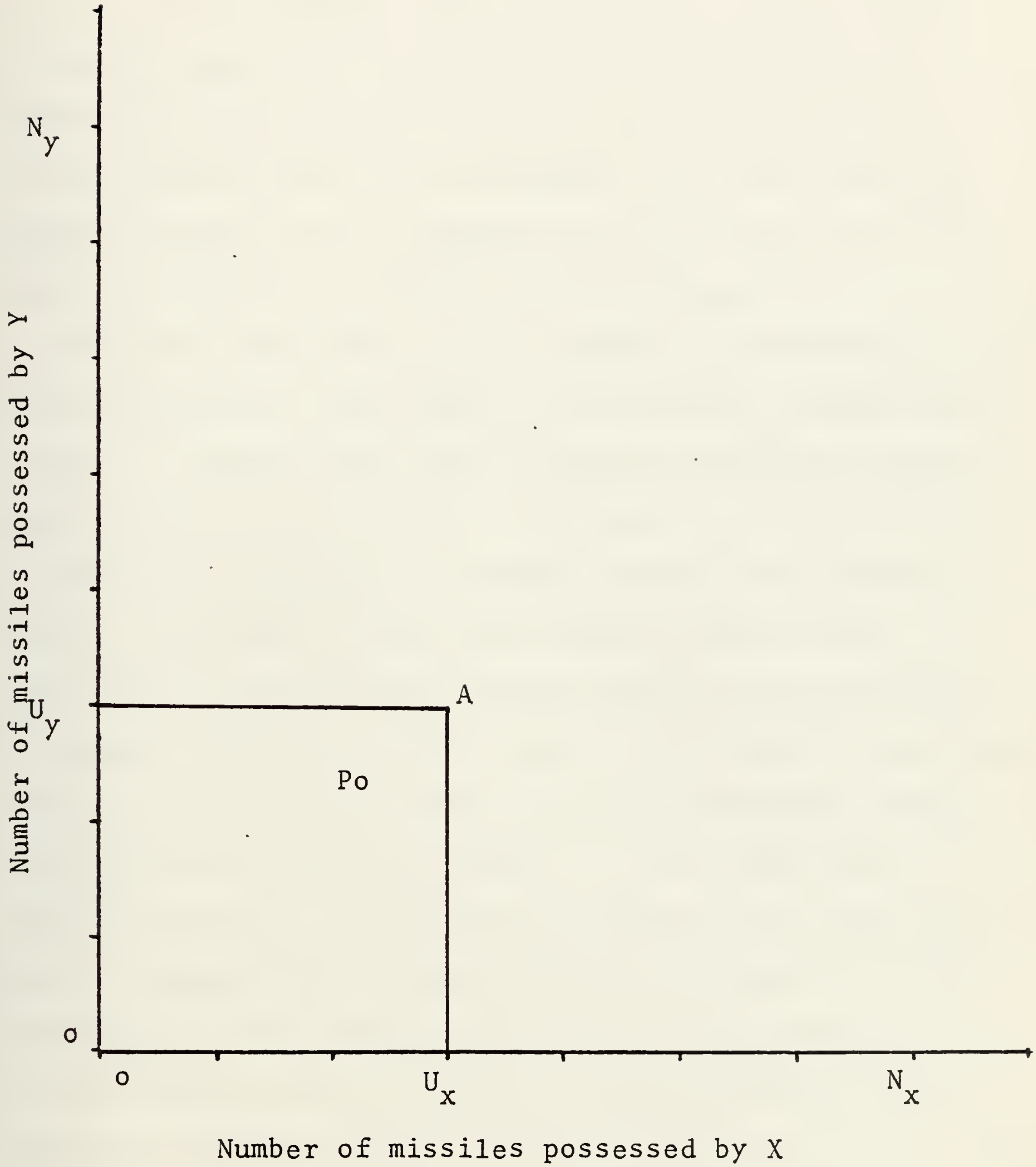

Figure 6. Threshold of deterrence

assumption is made that U_x and U_y points are where X and Y are deterred. U_x and U_y actually represent the number of missiles (warheads) that must survive a first strike (commonly known as the second-strike force) which are launched by the attacked country against the attacker's cities (countervalue) and are capable of inflicting unacceptable damage to her population and industrial capacity. Hence, the theory of mutual assured destruction.

When the point $P(N_x, N_y)$ in Figure 6 is outside the corner marked "no deterrence," the situation becomes more complex. Suppose that X has a number N_x missiles greater than U_x (that is, $N_x > U_x$). X can keep U_x of his missiles in reserve to threaten Y's cities and use the remaining (N_x-U_x) to attack Y's missiles (counterforce strike). If the attack is initiated, a certain number of Y's missiles would be destroyed. The key factor which must be considered by X is how many of Y's missiles can be destroyed, using (N_x-U_x) missiles for the attack? If Y is left with at least U_y missiles, Y can retaliate against X's cities and inflict unacceptable damage. Hence, the deterrence model functions on the principle that unless the potential attacker can destroy enough missiles in a counterforce strike to reduce the number of missiles below the U_x or U_y level, the attacker is deterred. The potential attacker would not have a first-strike capability and the attacked country would have a second-strike capability.

The number of missiles that could be destroyed in a counterforce strike depends on a number of factors, among which are the accuracy and warhead yield of the attacking missiles and the vulnerability (hardness) of the missiles under attack.

Suppose that C_x designates the probability that, if one of X's missiles is fired at, one of Y's missile silos, the target will be destroyed. Conversely, the probability that one of Y's missiles can destroy one of X's missile silos is designated C_y. The coefficients C_x and C_y are called the "coefficients of counterforce effectiveness" of X and Y's missiles, respectively.

Submarines at sea are considered invulnerable; hence the C_x and C_y counterforce coefficients would be equal to zero. Both the U.S. and U.S.S.R. have a second-strike capability deployed on submarine-launched ballistic missile (SLBM) platforms. This launcher platform invulnerability increases the stability of the deterrence and reduces the probability of either side initiating a first-strike counterforce attack. In this model, Figure 7, there is no counterforce capability.

If there is no effective ABM defense for the cities, then the conditions for mutual deterrence are simply $N_x > U_x$, $N_y > U_y$. All $P(N_x, N_y)$ points on Figure 7 in the large area above and to the right of a point A represent a state of mutual deterrence. If a point P is in the small

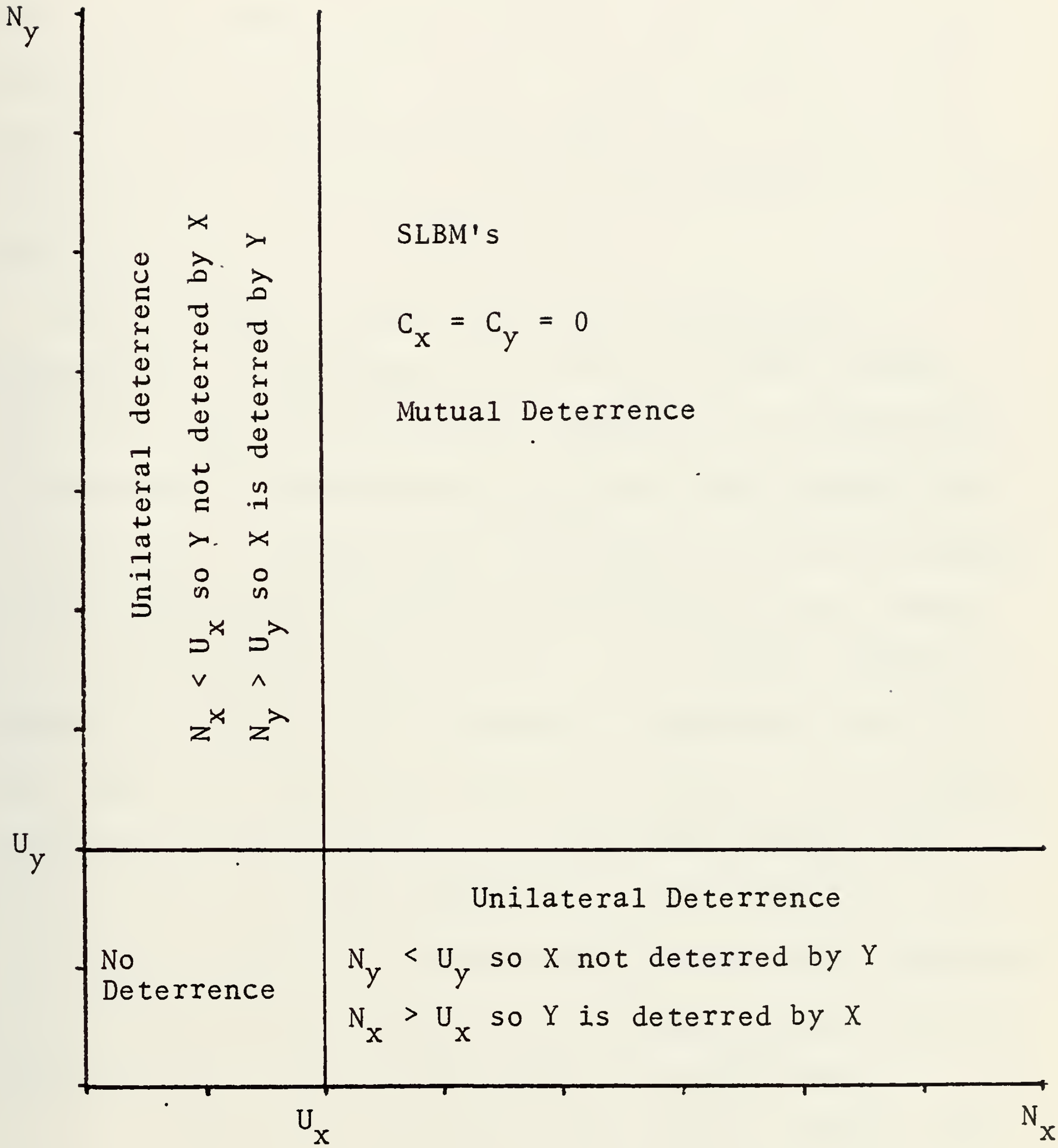

Figure 7. Possible deterrent situation for zero counterforce capability.

rectangle to the lower left, there is no deterrence. Two other zones remain labeled unilateral deterrence. In the lower zone, right of U_xA on Figure 7, $N_y < U_y$ so X is not deterred by Y, but $N_x > U_x$ so Y is deterred by X. Similarly, in the upper left zone, above U_yA, $N_x < U_x$ so Y is not deterred by X, but $N_y > U_y$ so X is deterred by Y. These two areas are

Next consider the case where the coefficients of counterforce effectiveness (C_x and C_y) are both greater than zero (but less than one). Assume X is contemplating a counterforce strike using $(N_x - U_x)$ missiles against the N_y silos of Y. As previously discussed, everything depends on the number of Y's missiles which survive after absorbing a counterforce strike from X. If X is not capable of destroying enough of Y's missiles to reduce her force to less than U_y, X will not be able to strike. As an example, suppose that the thresholds of deterrence are $U_x = 100$ and $U_y = 100$. In this example, U_x is the U.S. and U_y is the U.S.S.R. These are theoretical numbers which represent an acceptable damage against an undefended defense posture assuming each country subscribes to the MAD theory.

To construct more accurate force levels, defense (ABM and air), civil defense, systems reliabilities and losses due to a possible first strike comparisons must be considered and factored into the model. SALT negotiations limited the number of ABM sites each country can deploy

(100 interceptor missiles at each of two sites) and the U.S. recently decommissioned the only site completed in this country. Hence the Soviets have an advantage with their operational ABM Moscow site. The Soviets maintain an elaborate anti-bomber defense compared to the U.S., decreasing the probability of our bombers penetrating the defenses and striking their assigned targets. Civil defense has a high priority in the U.S.S.R. to protect their population and industrial base as compared to no conscious preparation and practice for civil defense in the U.S. These factors increase the number of warheads the U.S. must maintain in its inventory to inflict unacceptable damage on the Soviet population.

For the purpose of constructing this model, these factors will not be considered in the interest of keeping the model simple to demonstrate concepts. All these factors obviously would have to be considered and factored into the "real-world" model force level computations.

The U_x = 100 and U_y = 100 thresholds are indicated on Figure 8, which also shows a number of points P, all representing N_x = 1050 missiles for X, but various numbers N_y for Y. For this model the counterforce effectiveness coefficient C_x is 0.5 so that a missile belonging to X and aimed at one of Y's silos has a 50 per cent probability of destroying it, commonly known as "terminal Kill Probability."

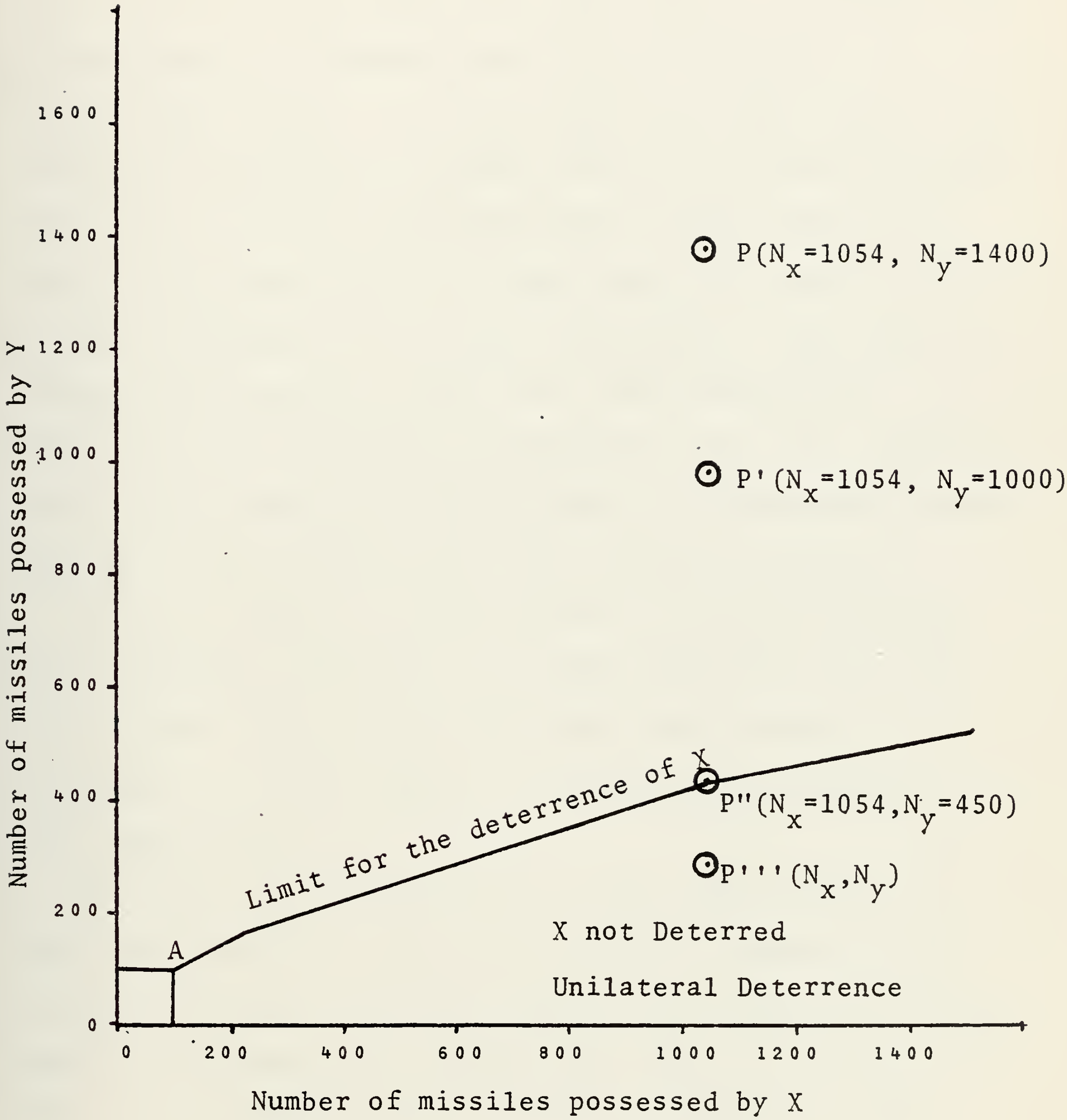

Figure 8. Deterrence of X by Y.

Consider first the point $P(N_x, N_y)$, for which $N_x = 1050$ and $N_y = 1600$. X could launch $(N_x - U_x) = 1000$ missiles against 1000 of Y's 1600 silos. But with X's C_x being 0.5, X could expect to destroy only 500 of Y's silos (0.5 x 1000 = 500). Y's silos remaining (1600 - 500 = 1100) would be sufficient to destroy X eleven times over considering that $U_y = 100$ is the unacceptable damage level of X. Clearly P is well within the zone where X is deterred by Y from attempting a disarming first strike. Take the example now where N_y is less than 1600 missiles, as illustrated by the series of points P', P'', P''', and P'''', all of which have $N_x = 1050$ missiles. A unilateral disarmament by Y could lead to just such a series of points.

At P', Y has $N'_y = 1000$ missiles. The 1000 missiles of X attacking 1000 silos of Y would leave 500 surviving (0.5 x 1000 = 500), still five times the tolerable threshold $U_y = 100$. Hence P' is inside the zone where X is deterred by Y.

Now take the case with $N_y'' = 450$, marked by P''. With 1000 missiles to aim at 450 silos, X can now afford to aim two of his missiles at each of 350 silos, and three each at the remaining 100 silos, so (350 x 2) + (100 x 3) = 700 + 300 = 1000 missiles. Employing probability laws, the number of silos expected to survive the attack will be 350 x 0.5 x 0.5 = 87.5 of those attacked by two missiles apiece, plus 100 x 0.5 x 0.5 x 0.5 = 12.5 of those attacked

by three missiles apiece, for a total of 87.5 + 12.5 = 100 missiles surviving out of the 450. One hundred Y missiles remaining is the threshold of deterrence U_y, enabling Y to retaliate with his second strike and inflict unacceptable damage on X. Hence, when $N_y \geq 450$, X is deterred from attacking Y, but when $N_y < 450$, X is not deterred.

P'' marks the point between a state of mutual deterrence and a state of unilateral deterrence, unilateral deterrence being in a state where X is not deterred, i.e., below the state of mutual deterrence. P''' and P'''' are well into the unilateral zone where X is not deterred from launching a counterforce first-strike against Y and where Y would not have enough surviving missiles to inflict unacceptable damage on X. SLBM's are not considered in this example.

This model has thus far assumed the counterforce effectiveness (C_x) of X's missiles to be 0.5. Assume the C_x value were higher; the number of missile silos Y must have (N''_y), which is providing the deterrence, would have to be larger in order to have at least $U_y = 100$ survive the attack by $(N_x-U_y) = 1000$ missiles. Assume that the accuracy of missiles improves by a factor of two every five years and X reduces the CEP of his missiles to a counterforce coefficient of 0.9 ($C_x = 0.9$). If $U_y = 100$ missiles were to survive, Y would require 1000 missiles in his force ($1000 \times 0.9 = 900 + 100\ U_y = 1000$). Should X increase

the counterforce coefficient to 1 ($C_x = 1$), Y would need 1100 missiles (1000 x 1 = 100 + 100 Uy = 1100) to deter X.

This model has thus far fixed the number of X's missiles at $N_x = 1050$. Leaving U_x, U_y, and C_x fixed, N_x will be varied and the geometric locus of P'' determined for all values of N_x. The object of the calculation is to construct a continuous curve joining all the points P'' (N_x, N''_y) such that an attack by (N_x-U_x) missiles against N_y'' silos would leave precisely U_y silos undamaged. The curve AP'' on Figure 9 shows this locus, and it will be referred to as the limit for the deterrence of X. Every point P' (N_x, N'_y) falling above the limit of deterrence curve represents a state in which X is deterred. All points P''' (N_x, N_y''') falling below the curve represent a state in which X is not deterred and has the ability to launch a counterforce first-strike, destroying enough of Y's missiles, $U_y > 100$, where Y cannot inflict unacceptable damage on X.

Thus far this model has addressed only the deterrence of X by Y. Using the same methodology, the deterrence of Y by X can be calculated and the limit for the deterrence of Y curve constructed. To every number of missiles N_y possessed by Y there corresponds a number of silos N''_x belonging to X, such that an attack by (N_y-U_y) missiles against the N''_x silos will leave exactly U_x surviving, just the number needed to deter Y.

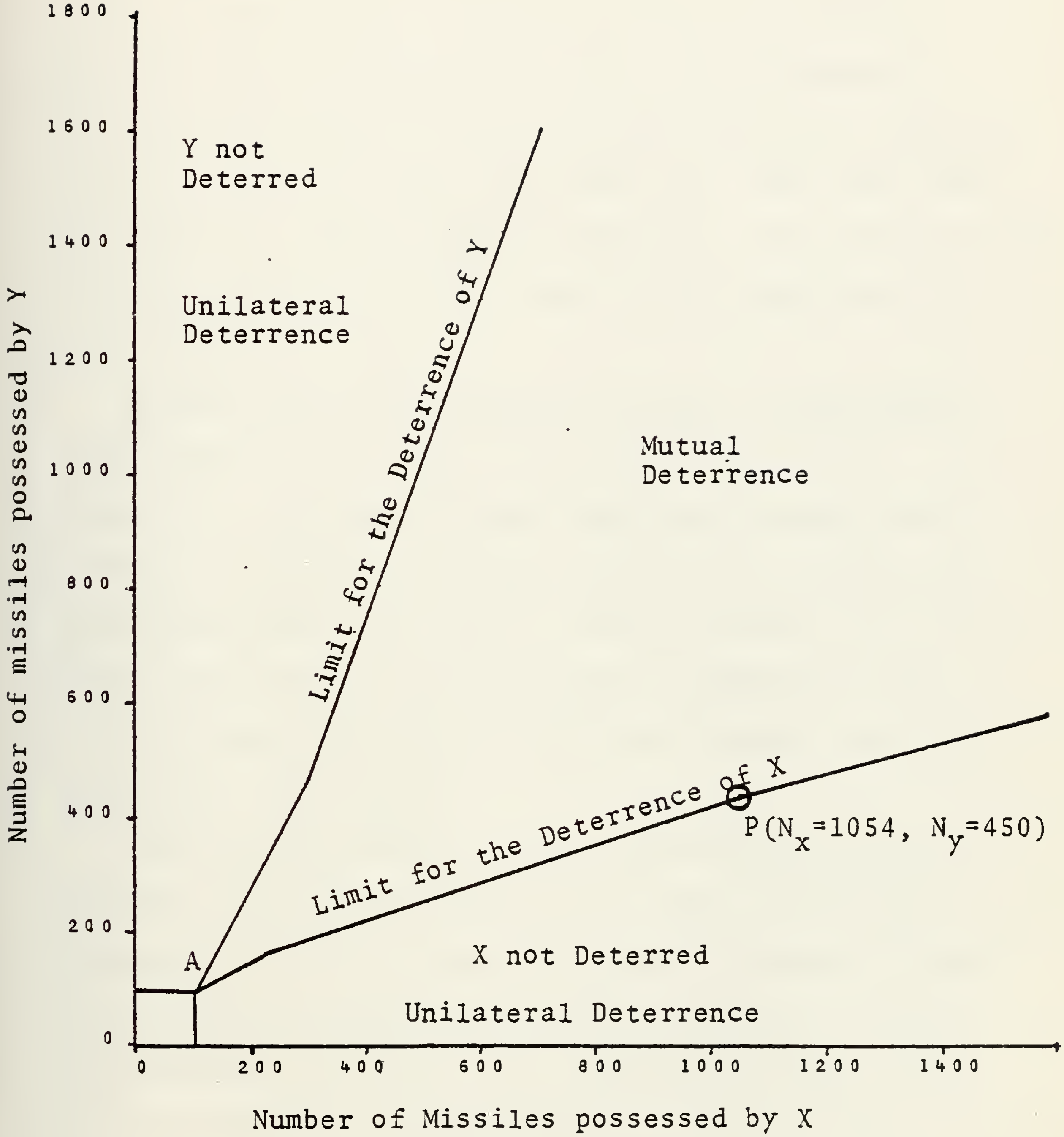

Figure 9. Limits for the deterrence of X and Y.

Figure 9 depicts both "limit for the deterrence" curves, labeled AP and AQ. All points falling to the right of AQ represent a situation where Y is deterred and all points falling to the left, Y is not deterred. All points falling in the zone between AQ and AP represent a state where both X and Y are deterred. This zone shall be labeled the zone of mutual deterrence. The curves AQ and AP were constructed using a counterforce coefficient of 0.5. ($C_x = C_y = 0.5$).

Another model was constructed using a counterforce coefficient of 0.9, $C_x = C_y = 0.9$, and $C_x = C_y = 0$, Figure 10. The zone of mutual deterrence becomes much narrower for high counterforce coefficients, making the deterrence model less stable. Notice the case $C_x = C_y = 0$, which occurs when all missiles are on submarines; the zone of mutual deterrence is very large making the deterrence model very stable.

The deterrence model has been constructed thus far assuming each attacking missile has only one warhead. Assuming all targeted silos are spaced a greater distance apart than the lethal diameter of the attacker's weapon aimed against those silos, the greatest possible coefficient of counterforce effectiveness of the attacker missiles is $C_x = 1$. However, MIRVed missiles contain more than one warhead which further complicates the model. Assume each missile contains n_x separate warheads; then

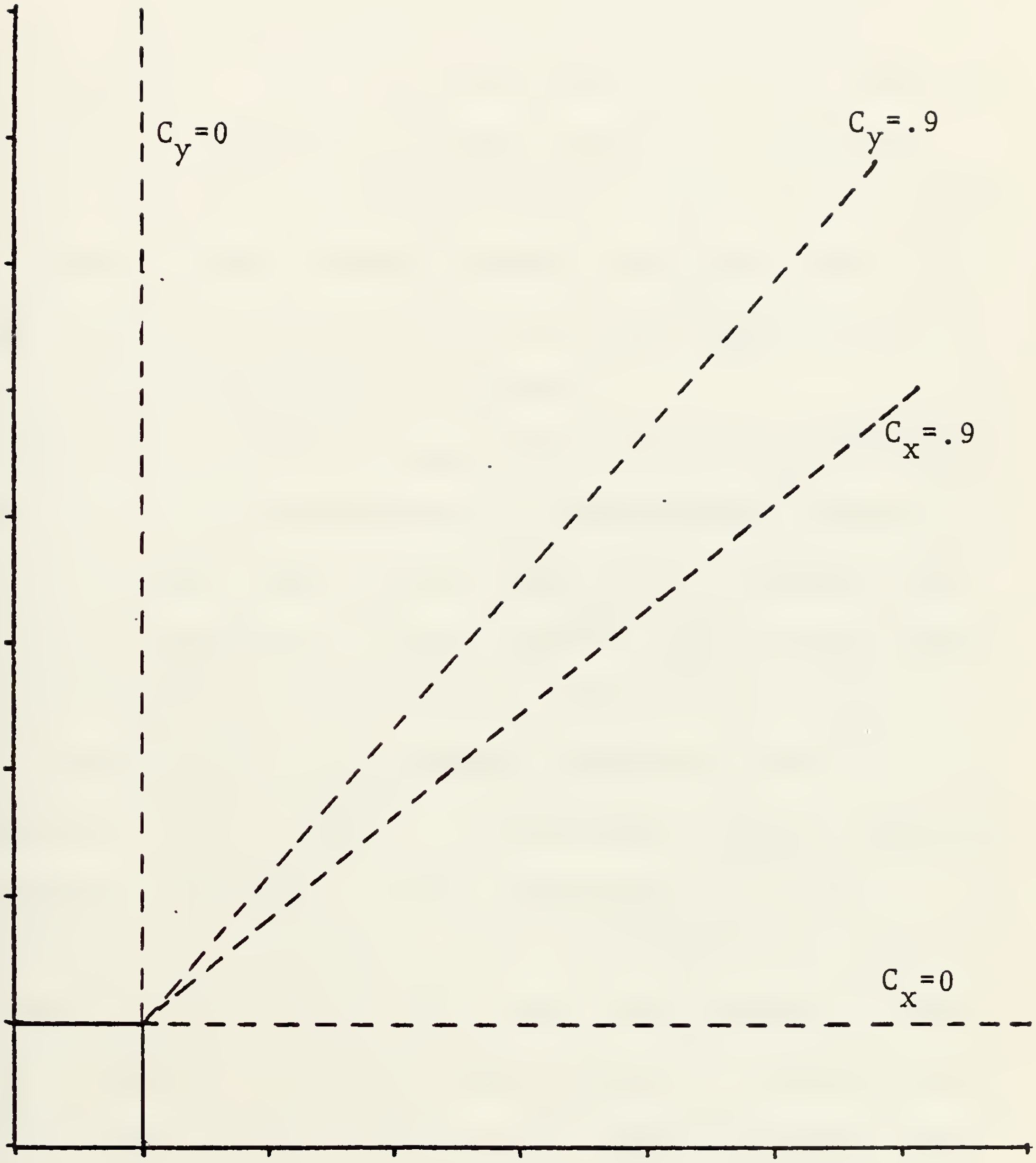

Figure 10. Variation in the limits of the deterrence zones as a function of counterforce efficiency.

one missile may be able to destroy more than one silo. As in the previous example, C_x and C_y are the probabilities that one of the warheads will destroy the silo it is targeted against. C_x or C_y will probably be less than one. However, considering the increased number of available warheads, it is quite possible that by being able to target more warheads in one missile against the same target, the probability could become greater than one ($n_x C_x > 1$). Figure 11 illustrates this situation.

Developing the model using MIRV's, the expected number of missiles (silos) destroyed in a counterforce attack by (N_x-U_x) missiles, each with n_x individually targeted warheads in each missile, and each warhead with an individual probability of C_x of destroying a silo, is the same as for an attack by $(N_x-U_x)n_x$ single missiles, each with a coefficient of C_x. Figure 11 illustrates a double unstable zone between the limit for the deterrence of X and Y.

Each missile carrying n_x small warheads will carry less total explosive yield than one large warhead of the same throw weight, but since each warhead is independently targeted, each re-entry vehicle will have a separate TKP, increasing the probability of destroying a targeted silo. This doubly unstable zone is the result of one silo being targeted by more than one warhead yielding TKP's which exceed one ($n_x C_x > 1$). The significance of this double unstable zone is that either side could launch a

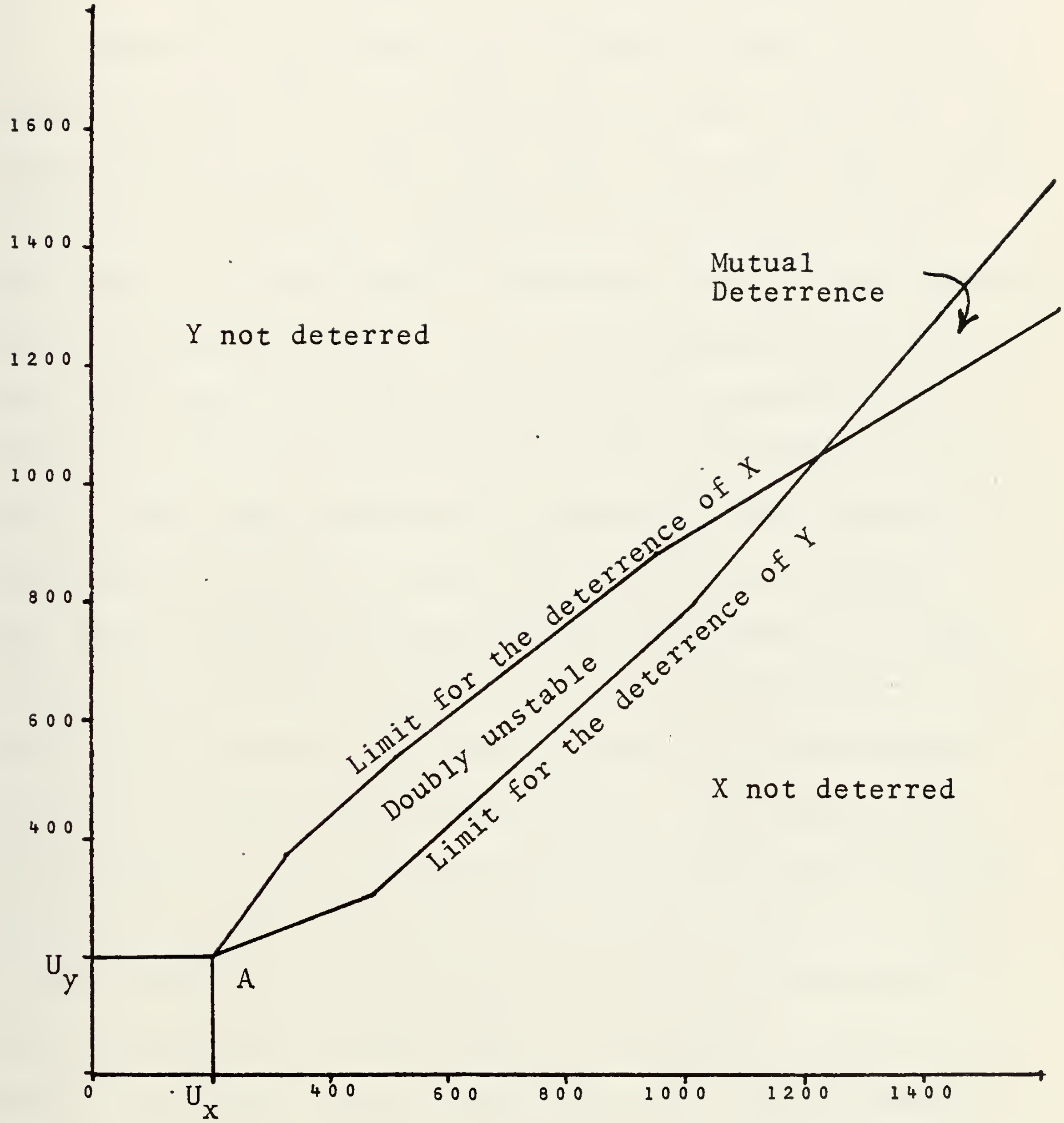

Figure 11. Limits of the deterrence zones when counterforce efficiency exceeds unit.

counterforce first strike to destroy the other's silos and the attacker would still have enough missiles remaining to launch an effective countervalue strike against his cities.

Figure 11 illustrates the deterrence zones of X and Y, assuming that both n_xC_x and N_yC_y are greater than one. The curves start at the point $A(U_x, U_y)$; the upper right corner of the "no deterrence" rectangle are enclosed by OU_xAU_y. This model is significantly different from the single-warhead missile model discussed. The curve marking the limit for the deterrence of X starts from A with a slope of n_xC_x, making an angle of more than 45° to the horizontal axis of N_x. For larger values of N_x there are more targeted warheads than there are silos and the slope is reduced. The curve marking the limit for the deterrence of Y starts from A with a slope of less than 45° to the horizontal axis. This slope increases for larger values of N_y where there are more targeted warheads than silos. The slope of the first segment of the curve marking the limit for the deterrence of Y, which also begins at A, has a slope of $1/n_yc_y$. If the slope is less than the second, a zone of mutual deterrence opens out from point A. However, if the curve marking the limit for the deterrence of X should commence at A with a larger slope than the other curve, then the two curves enclose a zone where neither X nor Y is deterred, and each has a first-strike capability. The condition for the existence of a double unstable zone

is then $n_x C_x > 1/n_y C_y$ or $n_x C_x n_y C_y > 1$. MIRV contributes two separate outputs to the deterrence model. In a counterforce role, double unstable zones result and in a countervalue role deterrence is reinforced since a greater number of smaller warheads can more efficiently distribute lethal damage over a population center than one large warhead.

In constructing the previous models three states of deterrence were identified: mutual deterrence, unilateral deterrence, or no deterrence. As previously discussed, deterrence is what prevents attack. To further develop the significance of these models, the concept of stability will be developed. Stability could be defined as the absence of a rational motive to launch an attack. When a rational motive exists on either side to launch a first strike, there is instability. However, since both powers have a formidable invulnerable second-strike capability, the country that launches a first strike must expect to absorb unacceptable damage. As a result of this potential unbearable punishment, deterrence evolves.

Instability is not the simple converse of deterrence. It is possible to have a state of stable deterrence or of unstable deterrence. Stability is not necessarily associated with near equality of forces on both sides either. Assume X possesses a very large force but Y does not have enough missiles to inflict punishment on X by an unopposed countervalue first strike; a stable and unilateral

deterrence state would exist. Y would be deterred by X but X would not be deterred. Should Y begin accumulating missiles, alarming X over the intended use of these warheads, X could disarm Y before reaching the threshold of deterrence U_y, and the state of unilateral deterrence would have become unstable.

Figure 12 illustrates these points. The curve AP'' represents the limit for the deterrence of X. Assume a situation where the number of missiles falls on a point lying below AP''; X would not be deterred from making a counterforce strike against Y's silos intending to disarm Y. Y realizing the lack of capability to attack X with complete success is deterred by X. Hence all area below AP'' represents a state of unilateral deterrence. However, the zones marked P''' and P'''' are markedly different. The zone P''' is an area where N'''_y U_y which means Y has more missiles than required for the threshold of deterrence U_y. Should Y use these missiles to launch an intolerable countervalue strike against X, X would have sufficient missiles remaining to annihilate Y's cities resulting in a suicidal act by Y. However, Y would possess the capability to conduct such an attack and X has the capability to then annihilate Y; hence this zone is labeled unstable unilateral deterrence. The zone labeled P'''' is an area where Y does not possess the missiles to inflict unacceptable damage to X's cities. Under these circumstances X would have no

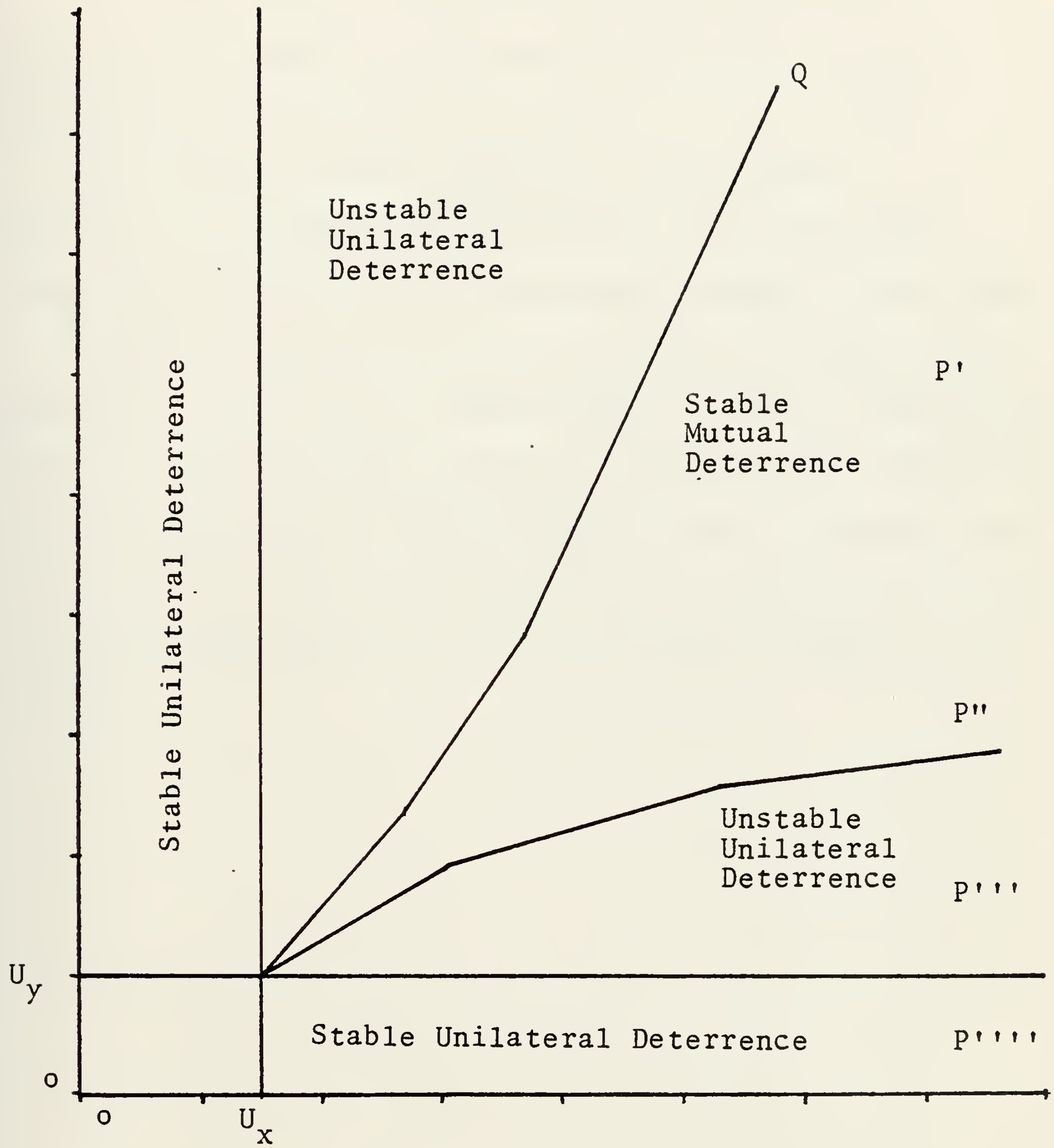

Figure 12. Stable and unstable deterrence.

rational motive for attacking Y and hence the zone is labeled state unilateral deterrence.

The curve AQ is the reciprocal of the curve AP'' and all factors apply to the zone to the left of AQ as those applied to the zone below AP''.

The rectangle marked OU_xAU_y is a zone without deterrence or instability since neither side possesses enough missiles to inflict unacceptable damage on the other.

The zone labeled AQ and AP is an area of stable mutual deterrence. All points (combinations of X and Y's missiles) falling in this zone will result in stable mutual deterrence since neither side has the ability to launch a counterforce first strike and destroy enough silos to keep the other side from retaliating and inflicting unacceptable damage on the attacker.

APPENDIX G

SALT NEGOTIATIONS AGREEMENTS

The following pages consist of documents and agreements between the United States and the Soviet Union from the Strategic Arms Limitation talks.

UNION OF SOVIET SOCIALIST REPUBLICS

Limitation of Strategic Offensive Arms

Interim agreement and protocol signed at Moscow on May 26, 1972; entered into force October 3, 1972, with agreed interpretations, common understandings, and unilateral statements.

INTERIM AGREEMENT
BETWEEN THE UNITED STATES OF AMERICA
AND
THE UNION OF SOVIET SOCIALIST REPUBLICS
ON CERTAIN MEASURES WITH RESPECT TO THE
LIMITATION OF STRATEGIC OFFENSIVE ARMS

The United States of America and the Union of Soviet Socialist Republics, hereinafter referred to as the Parties,

Convinced that the Treaty on the Limitation of Anti-Ballistic Missile Systems (1) and this Interim Agreement on Certain Measures with Respect to the Limitation of Strategic Offensive Arms will contribute to the creation of more favorable conditions for active negotiations on limiting strategic arms as well as to the relaxation of international tension and the strengthening of trust between States,

Taking into account the relationship between strategic offensive and defensive arms,

Mindful of their obligations under Article VI of the Treaty on the Non-proliferation of Nuclear Weapons,[1]

Have agreed as follows:

Article I

The Parties undertake not to start construction of additional fixed land-based intercontinental ballistic missile (ICBM) launchers after July 1, 1972.

Article II

The Parties undertake not to convert land-based launchers for light ICBMs or for ICBMs of older types deployed prior to 1964 into land-based launchers for heavy ICBMs of types deployed after that time.

Article III

The Parties undertake to limit submarine-launched ballistic missile (SLBM) launchers and modern ballistic missile submarines to the numbers operational and under construction on the date of signature of this Interim Agreement, and in addition to launchers and submarines constructed under procedures established by the Parties as replacements for an equal number of ICBM launchers of older types deployed prior to 1964 or for launchers on older submarines.

Article IV

Subject to the provisions of this Interim Agreement, modernization and replacement of strategic offensive

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[1]TIAS 6839; 21 UST 490.

ballistic missiles and launchers covered by this Interim Agreement may be undertaken.

Article V

1. For the purpose of providing assurance of compliance with the provisions of this Interim Agreement, each Party shall use national technical means of verification at its disposal in a manner consistent with generally recognized principles of international law.

2. Each Party undertakes not to interfere with the national technical means of verification of the other Party operating in accordance with paragraph 1 of this Article.

3. Each party undertakes not to use deliberate concealment measures which impede verification by national technical means of compliance with the provisions of this Interim Agreement. This obligation shall not require changes in current construction, assembly, conversion, or overhaul practices.

Article VI

To promote the objectives and implementation of the provisions of this Interim Agreement, the Parties shall use the Standing Consultative Commission established under Article XIII of the Treaty on the Limitation of Anti-Ballistic Missile Systems in accordance with the provisions of that Article.

Article VII

The Parties undertake to continue active negotiations for limitation on strategic offensive arms. The obligations provided for in this Interim Agreement shall not prejudice the scope or terms of the limitations on strategic offensive arms which may be worked out in the course of further negotiations.

Article VIII

1. This Interim Agreement shall enter into force[1] upon exchange of written notices of acceptance by each Party, which exchange shall take place simultaneously with the exchange of instruments of ratification of the Treaty on the Limitation of Anti-Ballistic Missile Systems.

2. This Interim Agreement shall remain in force for a period of five years unless replaced earlier by an agreement on more complete measures limiting strategic offensive arms. It is the objective of the Parties to conduct active follow-on negotiations with the aim of concluding such an agreement as soon as possible.

3. Each Party shall, in exercising its national sovereignty, have the right to withdraw from this Interim Agreement if it decides that extraordinary events related to the subject matter of this Interim Agreement have jeopardized its supreme interest. It shall give notice of its decision

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[1]Oct. 3, 1972.

to the other Party six months prior to withdrawal from this Interim Agreement. Such notice shall include a statement of the extraordinary events the notifying Party regards as having jeopardized its supreme interests.

Done at Mowcow on May 26, 1972, in two copies each in the English and Russian languages, both texts being equally authentic.

FOR THE UNITED STATES OF AMERICA:	FOR THE UNION OF SOVIET SOCIALIST REPUBLICS:
([1])	([2])
President of the United States of America	General Secretary of the Central Committee of the CPSU

[1]Richard Nixon.

[2]L. I. Brezhnev.

PROTOCOL

TO THE INTERIM AGREEMENT BETWEEN THE UNITED STATES OF AMERICA AND THE UNION OF SOVIET SOCIALIST REPUBLICS ON CERTAIN MEASURES WITH RESPECT TO THE LIMITATION OF STRATEGIC OFFENSIVE ARMS

The United States of America and the Union of Soviet Socialist Republics, hereinafter referred to as the Parties,

Having Agreed on certain limitations relating to submarine-launched ballistic missile launchers and modern ballistic missile submarines, and to replacement procedures, in the Interim Agreement,

Have agreed as follows:

The Parties understand that, under Article III of the Interim Agreement, for the period during which that Agreement remains in force:

The U.S. May have no more than 710 ballistic missile launchers or submarines (SLBMs) and no more than 44 modern ballistic missile submarines. The Soviet Union may have no more than 950 ballistic missile launchers on submarines and no more than 62 modern ballistic missile submarines.

Additional ballistic missile launchers on submarines up to the above-mentioned levels, in the U.S. over 656 ballistic missile launchers on nuclear-powered submarines, and in the U.S.S.R. over 740 ballistic missile launchers on nuclear-powered submarines, operational and under construction, may become operational as replacements for

equal numbers of ballistic missile launchers of older types deployed prior to 1964 or of ballistic missile launchers on older submarines.

The deployment of modern SLBMs on any submarine, regardless of type, will be counted against the total level of SLBMs permitted for the U.S. and the U.S.S.R.

This Protocol shall be considered an integral part of the Interim Agreement.

Done at Moscow this 26th day of May, 1972.

FOR THE UNITED STATES OF AMERICA	FOR THE UNION OF SOVIET SOCIALIST REPUBLICS
President of the United States of America	General Secretary of the Central Committee of the CPSU

AGREED INTERPRETATIONS, COMMON UNDERSTANDINGS, AND UNILATERAL STATEMENTS

1. Agreed Interpretations

(a) Initialed Statements. The document set forth below was agreed upon and initialed by the Heads of the Delegations on May 26, 1972:

Agreed Statements Regarding the Interim Agreement between The United States of America and The Union of Soviet Socialist Republics on Certain Measures with Respect to the Limitation of Strategic Offensive Arms.

(A)

The Parties understand that land-based ICBM launchers referred to in the Interim Agreement are understood to be launchers for strategic ballistic missiles capable of ranges in excess of the shortest distance between the northeastern border of the continental U.S. and the northwestern border of the continental U.S.S.R.

(B)

The Parties understand that fixed land-based ICBM launchers under active construction as of the date of signature of the Interim Agreement may be completed.

(C)

The Parties understand that in the process of modernization and replacement the dimensions of land-based ICBM silo launchers will not be significantly increased.

(D)

The Parties understand that during the period of the Interim Agreement there shall be no significant increase in the number of ICBM or SLBM test and training launchers, or in the number of such launchers for modern land-based heavy ICBMs. The Parties further understand that construction or conversion of ICBM launchers at test ranges shall be undertaken only for purposes of testing and training.

(E)

The Parties understand that dismantling or destruction of ICBM launchers of older types deployed prior to 1964 and ballistic missile launchers on older submarines being replaced by new SLBM launchers on modern submarines will be initiated at the time of the beginning of sea trials of a replacement submarine, and will be completed in the shortest possible agreed period of time. Such dismantling or destruction, and timely modification thereof, will be accomplished under procedures to be agreed on in the Standing Consultative Commission.

(b) Common Understandings. Common understanding of the Parties on the following matters was reached during the negotiations:

A. INCREASE IN ICBM SILO DIMENSIONS

Ambassador Smith made the following statement on May 26, 1972:

The Parties agree that the term "significantly increased" means that an increase will not be greater than ten to fifteen per cent of the present dimensions of land-based ICBM silo launchers.

Minister Semenov replied that this statement corresponded to the Soviet understanding:

B. STANDING CONSULTATIVE COMMISSION

Ambassador Smith made the following statement on May 22, 1972:

The United States proposes that the sides agree that, with regard to initial implementation of the ABM Treaty's Article XIII on the Standing Consultative Commission (SCC) and of the consultation Articles to the Interim Agreement on offensive arms and the Accidents Agreement,[1] agreement establishing the SCC will be worked out early in the follow-on SALT negotiations; until that is completed, the following arrangements will prevail: when SALT is in session, any consultation desired by either side under these Articles can be carried out by the two SALT Delegations; when SALT is not in session, ad hoc arrangements

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[1]See Article 7 of Agreement to Reduce the Risk of Outbreak of Nuclear War between the United States of America and the Union of Soviet Socialist Republics, signed Sept. 30, 1971. TIAS 7186; 22 UST 1590.

for any desired consultations under these Articles may be made through diplomatic channels.

Minister Semenov replied that, on an ad referendum basis, he could agree that the U.S. statement corresponded to the Soviet understanding.

C. STANDSTILL

On May 6, 1972, Minister Semenov made the following statement:

In an effort to accommodate the wishes of the U.S. side, the Soviet Delegation is prepared to proceed on the basis that the two sides will in fact observe the obligations of both the Interim Agreement and the ABM Treaty beginning from the date of signature of these two documents.

In reply, the U.S. Delegation made the following statement on May 20, 1972:

The U.S. agrees in principle with the Soviet statement made on May 6 concerning observance of obligations beginning from date of signature but we would like to make clear our understanding that this means that, pending ratification and acceptance, neither side would take any action prohibited by the agreements after they had entered into force. This understanding would continue to apply in the absence of notification by either signatory of its intention not to proceed with ratification or approval.

The Soviet Delegation indicated agreement with the U.S. statement.

2. Unilateral Statements

(a) The following noteworthy unilateral statements were made during the negotiations by the United States Delegation:

A. WITHDRAWAL FROM THE ABM TREATY

On May 9, 1972, Ambassador Smith made the following statement:

The U.S. Delegation has stressed the importance the U.S. Government attaches to achieving agreement on more complete limitations on strategic offensive arms, following agreement on an ABM Treaty and on an Interim Agreement on certain measures with respect to the limitation of strategic offensive arms. The U.S. Delegation believes that an objective of the follow-on negotiations should be to constrain and reduce on a long-term basis threats to the survivability of our respective strategic retaliatory forces. The U.S.S.R. Delegation has also indicated that the objectives of SALT would remain unfulfilled without the achievement of an agreement providing for more complete limitations on strategic offensive arms. Both sides recognize that the initial agreements would be steps toward the achievement of more complete limitations on strategic arms. If an agreement providing for more complete strategic offensive arms limitations were not achieved within five years, U.S. supreme interests could be jeopardized. Should that occur, it would constitute a basis for withdrawal

from the ABM Treaty. The U.S. does not wish to see such a situation occur, nor do we believe that the U.S.S.R. does. It is because we wish to prevent such a situation that we emphasize the importance the U.S. Government attaches to achievement of more complete limitations on strategic offensive arms. The U.S. Executive will inform the Congress, in connection with Congressional consideration of the ABM Treaty and the Interim Agreement, of this statement of the U.S. position.

B. LAND-MOBILE ICBM LAUNCHERS

The U.S. Delegation made the following statement on May 20, 1972:

In connection with the important subject of land-mobile ICBM launchers, in the interest of concluding the Interim Agreement the U.S. Delegation now withdraws its proposal that Article I or an agreed statement explicitly prohibit the deployment of mobile land-based ICBM launchers. I have been instructed to inform you that, while agreeing to defer the question of limitation of operational land-mobile ICBM launchers to the subsequent negotiations on more complete limitations on strategic offensive arms, the U.S. would consider the deployment of operational land-mobile ICBM launchers during the period of the Interim Agreement as inconsistent with the objectives of that Agreement.

C. COVERED FACILITIES

The U.S. Delegation made the following statement on May 20, 1972:

I wish to emphasize the importance that the United States attaches to the provisions of Article V, including in particular their application to fitting out or berthing submarines.

D. "HEAVY" ICBM's

The U.S. Delegation made the following statement on May 26, 1972:

The U.S. Delegation regrets that the Soviet Delegation has not been willing to agree on a common definition of a heavy missile. Under these circumstances, the U.S. Delegation believes it necessary to state the following: The United States would consider any ICBM having a volume significantly greater than that of the largest light ICBM now operational on either side to be a heavy ICBM. The U.S. proceeds on the premise that the Soviet side will give due account to this consideration.

(b) The following noteworthy unilateral statement was made by the Delegation of the U.S.S.R. and is shown here with the U.S. reply. On May 17, 1972, Minister Semenov made the following unilateral "Statement of the Soviet Side:"

Taking into account that modern ballistic middile submarines are presently in the possession of not only

the U.S, but also of its NATO allies, the Soviet Union agrees that for the period of effectiveness of the Interim "Freeze" Agreement the U.S. and its NATO allies have up to 50 such submarines with a total of up to 800 ballistic missile launchers thereon (including 41 U.S. submarines with 656 ballistic missile launchers). However, if during the period of effectiveness of the Agreement, U.S. allies in NATO should increase the number of their modern submarines to exceed the numbers of submarines they would have operational or under construction on the date of signature of the Agreement, the Soviet Union will have the right to a corresponding increase in the number of its submarines. In the opinion of the Soviet side, the solution of the question of modern ballistic missile submarines provided for in the Interim Agreement only partially compensates for the strategic imbalance in the deployment of the nuclear-powered missile submarines of the U.S.S.R. and the U.S. Therefore, the Soviet side believes that this whole question, and above all the question of liquidating the American missile submarine bases outside the U.S., will be appropriately resolved in the course of follow-on negotiations.

On May 24, Ambassador Smith made the following reply to Minister Semenov:

The United States side has studied the "statement made by the Soviet side" of May 17 concerning compensation for submarine basing and SLBM submarines belonging to third

countries. The United States does not accept the validity of the considerations in that statement.

On May 26, Minister Semenov repeated the unilateral statement made on May 24. Ambassador Smith also repeated the U.S. rejection on May 26.

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